MOTORCYCLE AMBULANCE SERVICE

Understanding Emergency Transport in Kigezi, Uganda and Developing an Innovative Solution

Abstract

This report details work done by the SSLP Uganda Maternal Health team in 2016. The team spent five weeks in Kabale, Uganda working with Kigezi Healthcare Foundation (KIHEFO) to learn about maternal health issues and develop an engineering solution for emergency transport for expectant mothers. This report may be used to (1) better understand transportation barriers for expectant mothers, (2) consider methodologies for field interviews and stakeholder evaluation, (3) evaluate data collected in user interviews, (4) gauge locally available prototyping resources and materials in Uganda, (5) review business models for delivering a motorcycle ambulance service.

Stanford University SSLP 2016 Uganda Maternal Health Team

September 16, 2016
Introduction
The 2016 Stanford SSLP Maternal Health team was tasked with improving maternal health services at a maternity ward operated by Kigezi Healthcare Foundation (KIHEFO). Having only been recently constructed and open to patients in March 2016, the maternity ward still faces many obstacles with patient recruitment, outreach and accessibility, identification and treatment of high-risk births, organizational and management workflow, workspace layout and design, and antenatal and postnatal care and education. Therefore, the purpose of the SSLP trip was to evaluate and identify specific needs that exist in KIHEFO’s maternal healthcare services and develop solutions that seek to mitigate them.

This report provides an overview of the 2016 SSLP Maternal Health project. It articulates the process the team underwent and the work that resulted from it. The report begins with an overview of the state of maternal healthcare in Uganda and background information on the Kabale region and healthcare services provided. It details our needfinding process, including insights from clinical immersion and field interviews with stakeholders in maternal health and emergency transportation. The report then discusses current transportation options and barriers to emergency transport for women in Kabale, Uganda, and a potential solution that could be adopted in this region: a motorcycle ambulance system. Next, we describe predicate motorcycle ambulance systems and list design requirements and constraints in selecting motorcycle ambulance components. We then describe our work in design, prototyping, and usage of predicate systems in order to collect more accurate user feedback. Lastly, we discuss the process behind creating an optimal business model for Kabale, Uganda and the financial model analysis and willingness to pay research that contributed to its selection.

Over the coming months, we plan to continue our efforts in acquiring an emergency transport system outlined in this report for KIHEFO to use for its maternity ward and rural health outreach services. We hope to obtain an initial system to conduct further compatibility testing and sensitization interviews before encouraging product deployment to communities across Kabale.

Background
This section provides the context through which the problem statement was investigated. It includes a brief history of maternal health in Uganda, including current statistics on maternal health in the country as compared to the global setting; an overview of the Kigezi/Kabale region; and a description of the local partner organization, KIHEFO, and the services they provide.

History of Maternal Health in Uganda
Maternal mortality, defined by the World Health Organization (WHO) as the “death of a woman while pregnant or within 42 days of termination of pregnancy... from any cause related to or aggravated by the pregnancy or its management”, continues to be a global concern. Uganda has one of the highest maternal mortality rates (MMR) in the world, and it is estimated that 16 women die per day in childbirth. The four most common contributors to maternal deaths in Uganda are hemorrhages, sepsis, obstructed labor, or complications arising from indirect causes such as HIV or malaria. Currently, it is estimated that Uganda has an MMR of around 343 deaths out of every 100,000 live births – a reduction
from its MMR of 687 in 1990.\textsuperscript{iii} However, this number is nearly double the country’s Millennium Development Goal 5 target: an MMR of 131 out of every 100,000 live births by 2015.\textsuperscript{ii}

Recently, the Ugandan government created a number of policies in order to increase the number and capacity of health facilities and improve the care offered in these facilities. Some of these programs are dedicated to reducing the country’s MMR – however, these have been “minimally implemented” due to a lack of resources on all levels of government.\textsuperscript{iv} For instance, the reduction of the Uganda MMR has generally been attributed to an increase in the number of women delivering in the presence of a skilled birth attendant (SBA), or trained health workers who are able to intervene should complications arise during the birthing process, as opposed to traditional birth attendants (TBAs), or midwives who have not received formal medical training but had instead been trained by other TBAs. Initially, the government had tried to pilot a program that worked to provide TBAs with more skills, with the implication that TBAs would refer women to local hospitals if there were complications during the birthing process. However, in 2010, the government instituted a ban on traditional birth attendants, arguing that TBAs had strayed from their major role of referring.\textsuperscript{v} This ban has not been very effective, as many women continue to seek out care from TBAs as an affordable option for their delivery.

However, public awareness of maternal health issues has gradually been increasing, and a number of maternal health advocacy groups in Uganda have gained momentum in the past few years. In 2011, a petition was launched against the Ugandan government by the Centre for Health, Human Rights, and Development (CEHURD) after the deaths of Sylvia Nalubowa and Jennifer Anguko in childbirth.\textsuperscript{vi} Because the Ugandan government failed to provide sound maternal healthcare services, CEHURD argued that the government was in violation of the human rights listed in their constitution, including the right to health.\textsuperscript{vi} The petition culminated in the case \textit{Constitutional Petition No. 16 of 2011: Centre for Health, Human Rights and Development and others vs Attorney General} that was presented before the Ugandan Constitutional Court. In June 2012, the constitutional court dismissed the case, stating that it had no mandate to hear this case, as it dealt with “political questions” that could not be determined by the Judiciary.\textsuperscript{vii} However, on October 30, 2015, the Supreme Court overruled the constitutional court’s decision, stating that the Constitutional Court was obligated to hear the case as it concerned human rights issues that are outlined in the Ugandan Constitution.\textsuperscript{viii} As of September 1, 2016, the case has been officially reopened.\textsuperscript{x} This case has large implications for future maternal health policies, including those regarding emergency obstetric services, as approximately 80% of the population reside in areas with little or no access to these types of services.\textsuperscript{x}

Despite these controversies, the state of maternal healthcare in this country has greatly improved. In general, antenatal care and maternity services are offered free-of-charge to all mothers in all public or government institutions, although expecting mothers are often asked to bring supplies, such as gloves or basins, with them when they deliver in these health care facilities.\textsuperscript{x} The majority of mothers in Uganda attend at least one antenatal care visit, with an estimated one half of Ugandans attending more than four.\textsuperscript{x} Mothers attend these visits primarily to receive an antenatal card, which make it easier for women to be admitted in hospitals should they choose to deliver there, but also to ensure the health of the mother and baby.\textsuperscript{x} There are a number of factors that influence a woman’s decision to deliver at home or at a health facility, and generally include cultural beliefs or attitudes towards birth, social influences from family members, cost of care, lack of access to transportation, perceived rudeness or abusiveness from workers at formal healthcare facilities, habit, or unexpected “quickness” of labor or labor occurring at night.\textsuperscript{x}
Introduction to Kabale

The Kigezi region, located in Southwestern Uganda, has a population of nearly 2 million people. One of its districts, Kabale, has a population of around 530,000 people. Its main cultural group is Bakiga, while its main language is Rukiga. The majority of the population in Kigezi relies on agricultural practices in order to provide sustenance for their family and for other semi-commercial uses.

Figure 1: Kabale Town

Figure 2: Kabale's Landscape

In regards to healthcare access in this region, approximately 84% of the population lives within 5km of a health care facility in Kabale. However, Kabale still has a maternity mortality rate of 310 out of every 100,000 live births, and only 44% of births in this region occur in health care facilities. In Spring 2016, a study conducted by Joseph White entitled Preventing Unnecessary Deaths: Examining Barriers to Skilled Obstetric Care During Childbirth in Southwest Uganda concluded that the barriers that prevent women from seeking a skilled birth attendant during their delivery in the Kabale district included a fear of being neglected or poorly treated, far distances to health facilities, high costs, particularly in regards to transportation, and “health facility deficiencies such as inadequate staffing/training”.

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Introduction to KIHEFO
The Kigezi Healthcare Foundation (KIHEFO), founded by Dr. Geoffrey Anguyo, is a non-profit, non-governmental organization based in Kabale, Uganda. This organization works under the belief that issues such as “poverty, ignorance, and disease” are intertwined; thus, they work in a variety of fields regarding community development, including education, medical services, women's empowerment, and economic development, in order to reach families in Kabale. To facilitate the sustainability of their programs, KIHEFO works closely with communities to create programs that empower individuals and families, rather than simply “handing out” resources.

Figure 3: KIHEFO’s Main Clinic in Kabale Town

KIHEFO operates four separate clinics: a medical and dental clinic, maternity ward, HIV/AIDS clinic, and nutrition center. They also conduct general and HIV/AIDS outreaches, work with traditional healers and TBAs to extend local referral systems, provide vocational training, and lead projects designed to meet specific community needs (e.g., a rabbit farm to combat malnutrition and provide economic opportunities for poorer families).

In March, KIHEFO built a maternity ward meant to provide mothers and their families with a safe space to give birth. The ward currently employs five midwives and holds general antenatal care visits every Thursday. During these visits, the midwives collect patient histories, conduct physical examinations and blood tests, and monitor the general health of the mother during her pregnancy. Additionally, the midwives advise the mother on how to prepare for her upcoming delivery, including information on her diet and what materials to bring when she returns to the clinic for her delivery. In cases of extreme complications during the birthing process, the midwives refer mothers to a local hospital located 1.5 km away from the maternity ward, although the referral transportation is provided by KIHEFO. The clinic relies on word-of-mouth advertising by their current patients in order to recruit expecting mothers. The ward also cares for mothers that show up before their expected due date and provides postnatal care and checkups for recently delivered mothers and their neonates.

Needs Identification
This section describes the process the team took to identify needs in the local community and a general summary of our results. Throughout this process, we hoped to (1) to familiarize ourselves with the state of maternal healthcare in southwest Uganda, (2) to observe problems regarding maternal health that KIHEFO and the greater Kabale region are facing, and (3) to select a well-scoped project to be worked on
within the five weeks of the program. The Maternal Health SSLP team underwent different methods of needs identification for maternal health, including clinical immersion and interviews with numerous stakeholders. The following sections outline the procedure behind and insights gained in each need-finding method.

Clinical Immersion
We began our needs identification by observing the various ways KIHEFO delivers healthcare to its patients. Throughout this process, we engaged in maternity ward and clinic immersion and attended outreaches to rural villages and communities, as well as monthly workshops for health education and check-ups.

Maternity Ward & Clinic
KIHEFO’s maternity ward was our first source of information. We visited the maternity ward on several occasions to speak with healthcare workers present and observe the delivery of care. The maternity ward strives to identify mothers that may experience high-risk births and require additional medical attention or procedures. The maternity ward is currently not at the capacity to confidently oversee complicated deliveries that may require special care. If a delivery is identified as high-risk at the onset or in the middle of labor, KIHEFO currently provides emergency transport with its ambulance van from the maternity ward to the Kabale General Hospital, located approximately 1-2 kilometers from the ward. However, in the present system, patients still need to find their own transportation to the maternity ward for care, assistance with deliveries, or transport to the Kabale General Hospital in high-risk cases.

One of the key considerations for maternity ward staff and administrators is the careful utilization of resources. As the ward has only been open for half a year, they have been extremely careful not to overextend the ward’s capacities. This is why ANC visits are only accepted one day a week and the ward’s services have not been broadcasted to more people. Additionally, there are currently only five midwives and a health practitioner on staff; thus, the ward is cautious about taking in too many patients to prevent a drop in the quality of care. Nonetheless, the ward is poised to see more patients and grow in its capacity over the next year. In order to accomplish this, KIHEFO is hoping redesign the physical
layout of the ward in order to maximize its physical space to see more patients, while still respecting patient privacy and comfort.

We also learned about and visited KIHEFO’s other healthcare services, such as its general and dental clinics. However, we spent less time in these clinics as we wanted to focus our efforts on better understanding our target population of stakeholders in the maternity ward.

Outreaches: Cervical/Breast Cancer Screening, General Health/HIV Screening

KIHEFO also provides a variety of community outreach services in order to reach populations in rural villages. These served as good opportunities for us to observe healthcare delivery in rural settings and learn about daily lifestyle for rural populations. In these community outreaches, KIHEFO staff, volunteers, and services are transported to one of the many communities that have established relationships with the organization. These outreaches are advertised through local churches, savings groups, and community leaders beforehand. Each month, there are three General Health Examination/HIV Screening camps. Twice a year, large General Health Examinations are also held for larger patient capacity. KIHEFO has also launched Women’s Health Camps, which include cervical and breast cancer screening and referrals, antenatal care services, and family planning.

In order to establish sustainable relationships with the local populations and continually see patients who may be unable to transport themselves to KIHEFO’s clinics in Kabale, these camps recur in the same communities - nonetheless, referrals to local healthcare facilities and KIHEFO’s clinics are still made if additional medical attention is deemed necessary.

During the program, we were able to attend an outreach for cervical and breast cancer screening near Kabale at Kamukira Health Center and another for general health examinations and HIV, syphilis, typhoid, and malaria screening in Ruhija (near the Impenetrable Forest). These outreaches allowed us to observe transportation methods, along with local terrain and roadwork in rural communities. Through shadowing and assistance in these outreaches, we were also able to learn about the question, concerns, and inefficiencies that plague rural healthcare.
Workshop: Nutrition Clinic
Lastly, we were also able to attend the monthly workshop that KIHEFO holds on nutrition education and checkup. This allowed us to learn about another way that KIHEFO encourages long-term care and relationships with hard-to-reach patients.

KIHEFO’s Nutrition Clinic workshops are mainly targeted at mothers of malnourished children, with the intent to educate them about healthy eating habits and necessary food intake balances. Currently, KIHEFO’s nutrition clinic houses up to six mothers and their children at a time; once the condition of the malnourished children improves and is deemed as healthy, mothers and children are released from the nutrition clinic. In order to ensure longitudinal care, KIHEFO holds monthly workshops to follow up on past patients, asking that they come back with their children so that the clinic can provide check-ups on their health and nutrition status and offer advice for any troubles they may be facing.

Stakeholder Interviews
Next, we interviewed various stakeholders in the state of maternal health in Uganda. This was necessary to gain a more holistic understanding of the need space through incorporation of multiple perspectives. Though we understand that others not listed in this section may also be considered stakeholders, we targeted people critical to the workflow for care and delivery and available for our inquiries, as specific to KIHEFO’s organizational structure.

Mothers
We were able to speak with many mothers through maternity ward visits and clinic shadowing. We mainly asked questions regarding family background and access to care. Some insights gained included information on incentives for accessing care, husband-wife relationships and family dynamics, birth complications, family planning, medical care financing, and transportation methods to the clinic.

Midwives
We also had the opportunity to speak with the midwives that work in KIHEFO’s maternity ward in order to gain a better understanding of maternal healthcare and maternity ward protocols. Discussion topics include procedural tasks such as initial and recurrent ANC visits and process for delivery, postnatal care, and referrals to Kabale General Hospital.

The midwives walked us through the physical examinations for pregnant women in order to educate us about ways to determine health of a patient and identify potential high-risk births. These included checking for malnutrition, anemia, and edema. Some indicators of high-risk births include the pregnant woman’s stature, fetal positioning, and information on past births. Additionally, we were taught about the medications prescribed on a monthly basis, as well as the laboratory tests recommended for each pregnant woman, such as HIV and syphilis screening, urine analysis, and blood typing. The midwives shared with us information on medical training to become a certified midwife, along with their differences from traditional birth attendants and healers that may exist in more rural communities. They also answered our questions regarding medical recordkeeping and visit costs, showing us antenatal voucher cards from the Ugandan Ministry of Health, which cover ANC visit finances, and booklets that teach women about healthy motherhood.

Additionally, the midwives shared information on necessities and preferences for women in labor. These include materials that mothers tend to bring, recommended positioning and discouraged actions for women in labor, and general protocols for carrying women in labor to and from the ambulance.
Traditional Healer/Traditional Birth Attendant
In order to better understand the practice of traditional medicine in Uganda, we also visited a traditional healer and several traditional birth attendants in a rural village bordering Lake Bunyonyi in southwest Uganda. The traditional healer is a leader in a traditional medicine network, and served as a great resource for our inquiries on the differences in delivery of care and patient relationships. We first learned about the different types of traditional healers: herbalists, who provide herbs to treat medical problems; witch doctors, who use witchcraft to cast out evil; diviners, who predict future happenings; and traditional birth attendants, who deal with women's issues, maternity, and pregnancy. The traditional healer also explained to us the current partnerships that exist between those who practice traditional medicine and hospitals and clinics, through which patients may be referred to healthcare facilities for further care. He recognized that not all conditions can be treated or cured by traditional medicine and encouraged a mixture of the two forms of medicine. We also learned about the methods in which people reach traditional healers, some coming by foot or stretcher from nearby rural communities and some coming by boat or motor vehicle from places as far as Rwanda, Tanzania, and Burundi.

Finally, we learned about the procedures for care that traditional birth attendants follow, which include monthly checkups with physical examinations and medical history collection starting from the fourth month of pregnancy. Expectant mothers are encouraged to go to a health center for additional antenatal care so that they can receive an antenatal card, which makes it easier for women to be admitted to hospitals in the case that complications arise during their delivery. The traditional birth attendants explained that they also guide mothers on healthy nutrition habits. Herbs are administered to mitigate and prevent complications. After birth, the traditional birth attendants are careful to check that the baby is healthy and will refer to a hospital if any problems are identified.

Ambulance Driver(s)
We interviewed KIHEFO's ambulance driver to learn more about the emergency transportation services offered by the organization. He had been driving the ambulance van since early 2016 and been trained to navigate the van safely and efficiently. Though he has occasionally driven to rural communities, the van is mainly used within town to transport patients to Kabale General Hospital - typically women in high-risk labor from the maternity ward. We asked about the training required to drive the van and other general information regarding his day-to-day schedule. He is notified of patients to pick up once a KIHEFO staff member reaches him by a phone call. He typically drives the ambulance at 80-90 kilometers per hour, though he may drive at 50 kilometers per hour for rockier terrains.
Figure 6: KIHEFO's Current Emergency Transport Vehicle

Finally, KIHEFO’s ambulance driver informed us about some of the challenges he had experienced driving the ambulance van. For example, it is difficult to use the ambulance van in rural areas because roads can be too narrow in more remote communities. Additionally, the ambulance van is hard to drive and requires training and practice, so only a few drivers operate the ambulance van.

KIHEFO Director/Physician (Dr. Geoffrey)
We met with physician and director of KIHEFO, Dr. Geoffrey Anguyo, on numerous occasions to better evaluate and understand the problem space of maternal health in Kabale, Uganda. He taught us about general family dynamics and gender imbalances in Ugandan culture, the present state of women’s issues and healthcare, and roadblocks to maternal healthcare improvements.

We also learned about community and healthcare facility structure within Uganda. Uganda has a unique healthcare system, designed to emulate its community structures. These are four levels of health centers, ranging from Health Center I’s, which are generally operated by volunteers and are focused on providing education to its communities, to Health Center IV’s, which are organized to serve 2-3 sub-counties (of 80,000 people each) and contain a small operating room. After these health centers, there are district and regional hospitals, designed to service 500,000 and 3 million peoples, respectively. There are also a number of private or non-governmental hospitals and clinics. Nearly 60% of Ugandans go first to non-governmental health organizations when seeking care, including 40% of those that fall within the lowest wealth quartile.

Lastly, he told us about problems that KIHEFO is facing and future goals for the organization. For example, clinic administrators at the maternity ward are trying to determine the best way to utilize its resources and facilities to care for patients, so that the ward can expand its patient inflow and improve upon its care in the upcoming months. Additionally, Dr. Anguyo shared with us his hopes for KIHEFO to get to hard-to-reach patient populations in rural communities. For the space of maternal health, he emphasized the inefficiencies of emergency transportation for mothers in labor in the status quo, explaining that women oftentimes have to walk to the nearest health facility or are forced to deliver at home because of inadequate and limited options. Unfortunately, KIHEFO’s current emergency transport system is reliant on the ambulance van, which Dr. Anguyo explained is less fuel-efficient compared to other options. Because of its high fuel demand and limited resources, KIHEFO has not been able to use it
frequently to reach rural communities. In the future, KIHEFO hopes to include these populations in its care, as to best serve those that may need it most.

**Needs Identified**
The results of our clinical immersion and field interviews confirmed and added context to needs previously identified in literature research and revealed many new needs previously unidentified. The following are some of the needs that we identified from this process. In determining the direction of our project, we discussed each need, taking into consideration available resources, usefulness for KIHEFO, time restrictions, and team capabilities:

1. Increase capacity for outreach health services
2. Expand recruitment strategies
3. Redesign maternity ward layout to maximize space utilization while ensuring privacy
4. Prepare postnatal packets/pilot services to ensure follow-up attention and education
5. Seek better emergency transport for outreach to rural communities
6. Improve services for premature babies, such as an incubator system
7. Provide health education opportunities during outreach health services
8. Improve birth preparedness with integrated family and financial planning

**Problem Statement**
Though many needs were identified, we ultimately focused on the problem that women in the Kigezi region of Uganda experience significant challenges transporting themselves to healthcare facilities during labor and delivery. As the state of maternal healthcare and emergency transportation in Uganda is multifaceted, the problem statement our team generated is broken down into three parts. Our problem statement is as follows:

1. To assess options for emergency transportation through design considerations and analysis.
2. To identify user pain points and evaluate user feedback for targeted product improvement.
3. To develop a sustainable business distribution and user provision model for the deployment of an improved emergency transport system.

In order to accomplish each of these problem statement subsections, we outlined a series of tasks that would need to be achieved.

**Task 1: Understanding Transportation Barriers for Maternal Healthcare**
To assess options for emergency transportation, we conducted need-finding through clinical and community immersion and stakeholder interviews, as well as literature review of past research.

**Task 2: Evaluating Motorcycle Ambulances as an Emergency Transport Solution**
We evaluated predicate products, developed a list of motorcycle ambulance design considerations, and collected information on manufacturing capabilities, resources, and costs.

**Task 3: Improving Motorcycle Ambulances for Application in Kigezi, Uganda**
We conducted a study to understand user pain points and preferences to recommend product improvements. To better engage our interview subjects and simulate the real-life product, we prototyped components of a motorcycle ambulance to aid in our interview process.
Task 4: Creating a Business Model for Providing Motorcycle Ambulance Service in Kigezi, Uganda
We conducted a willingness-to-pay study to better understand the user group. Additionally, we prepared a business and financial model to determine KIHEFO's current model for program sustainability.

Task 1: Understanding Transportation Barriers for Maternal Healthcare
The barriers to maternal healthcare remain numerous. One of the largest challenges we identified in the Kigezi region, however, was the absence of an affordable, comfortable and safe transportation method, for mothers in labor travelling to health centers for their deliveries. Commonly used modes of transport are by motorcars (cars), boda bodas (motorcycles for hire), stretchers, and foot (walking).

Transportation is a multipronged issue that reflects the intricacy of maternal healthcare. Understanding the topic further requires knowledge of the ‘Three Delays Model’, which addresses three particular pillars that may hinder access to maternal health care:

1. Delay in decision to seek care: This may occur due to a number of factors such as, limited awareness and knowledge about health center services, financial barriers, family dynamics, cultural norms and implications, etc.
2. Delay in reaching care: This pertains directly to the topic of transport while seeking maternal healthcare services. Factors such as transportation costs, road conditions, distance to the health center, and time of day, among others have far-reaching repercussions on mothers’ ability and willingness to pursue services at health centers (as will be explained further on).
3. Delay in receiving adequate health care: It is not uncommon for health centers to be undereqquipped or poorly resourced, especially in regions where it is difficult to acquire appropriate equipment or hire medical service administrators.

Financial barriers serve as one of the most daunting challenges to transportation availability and access. The prices vary depending on the mode of transport as well as the distance travelled. Additionally, many villages are only connected to the town by roads with rough terrain (often narrow and rocky), thereby making it extremely difficult for certain kinds of transport to penetrate into those communities. Other communities may simply not have transportation options readily available at mothers’ disposal if they are too far off from town, therefore pushing the waiting time for transport to a couple of hours, if not more. Time also played a critical role in seeking transport. One of the mothers we interviewed stated that she had to resort to a home birth because the chances of her being able to find transport at night were extremely small.

Before delving into the current transport space in southern Uganda, we decided to assess why conventional ambulances had not made their mark in the region yet. During our preliminary investigation into transportation modes for labour transits, we discerned several shortcomings with traditional ambulance vehicles and services. Firstly, traditional ambulance vehicles can only be driven by certified ambulance drivers who have a certain amount of medical experience and have been licensed to drive large vehicles (such as the traditional ambulance). Secondly, traditional ambulance vehicles cannot reach certain communities and villages because of their inability to navigate on narrow, unfriendly terrain (such as the narrow dirt, rocky roads) which are ubiquitous in the Kigezi region. Additionally, the costs of driving a traditional ambulance vehicle are very high and this transportation option has not served as economically feasible for most communities and villages. Such costs not only include initial capital expenditures, but also include the running repair and operation expenses of these fuel inefficient vehicles that encounter many maintenance issues while traversing the rough terrain in the region. The aforementioned points thereby render the traditional ambulance unsustainable and
unaffordable to the vast majority of mothers seeking transportation services for delivery. We then moved on to examining the other transport options available, and currently in use.

Cars are the most expensive option, but are less prevalent in distant villages and communities. They happen to be the most comfortable option in use, but their price overshadows the benefits of comfort to most people in the region. Cars are also unable to travel to communities that can only be reached by narrow dirt roads.

Boda bodas (motorcycles) serve as another transport option and tend to be widely available for hire. One factor that largely dictates their common use is their low prices (they tend to be substantially cheaper than cars). It is, however, not uncommon for boda drivers to demand higher rates if pregnant or ailing people request them to drive slower and ‘more cautiously’, simply because doing so on a motorcycle is a challenging task. Upon interviewing mothers who had used bodas during their delivery transits, we confirmed that sitting on the back of a boda was both painful and stressful for mothers in labour. Bumpy roads tended to exacerbate the condition of mothers (both physiologically and psychologically), and some mothers feared the chances of complications.

It is also important to note that some communities make use of stretchers, which are often provided through group initiatives. From our interviews with mothers in community groups, we learnt that members contribute to the group in some form of a financial way; most groups have a monthly fee in addition to a one-time entry fee (values vary quite substantially), and the money collected is used to pay for pooled resources. The Ngozi group, for example, saves money to pay for members’ medical bills and emergency transportation costs (in addition to burial and funeral costs). Stretcher services are often offered to the pregnant and the sick, as one of the benefits of being a part of the community group. Stretchers, however, by virtue of being manpowered, tend to be largely inefficient and it often takes hours to transport a patient to a health center which may be only a few kilometers away. Additionally, this method requires at least two people, if not more, since it is quite a tiresome and taxing task and it is common for people to rotate shifts carrying the stretcher.

If mothers do not have any of these transportation methods available, they either resort to walking, which can be a incredibly arduous experience, or they deliver in their homes with whatever minimal means they may have. Both of these may pose as grave risks, particularly if the mother requires emergency care and it is too far to be found.

With regards to KIHEFO, the organization is only able to use a traditional ambulance for the short (approximately 3km) patient referral journeys (from its maternity ward to one of the local hospitals) in the case that birth complications arise or if a procedure demands more resources (such as a cesaerian section) than what the ward can provide. The mothers, however, need to find their own transport for their initial journey to the maternity ward.

Given the dearth of an affordable, comfortable and sustainable transport option in the Kigezi region, we began exploring the possibilities of converting the motorcycle, currently the most ubiquitous vehicle, into a more safe transportation option for mothers going through labour. This was when we turned our heads towards the notion of the motorcycle ambulance carriage attachment.

**Task 2: Evaluating Motorcycle Ambulances as an Emergency Transport Solution**

In order to address this need statement, we decided to focus on motorcycle ambulances for our project. This was due to many reasons, including the shortcomings of other types of local emergency transport
options. These have been detailed above and provide motivation for looking at other emergency transport options. Additionally, motorcycle ambulances are a cheaper option, can navigate on rough terrain, and capitalize on the extensive motorcycle taxi service.

In 1992, the Ugandan market started to include motorcycles (also known as boda bodas or bodas), leading to a growth in the motorcycle market over the next several years. In part, this was due to new regulations by the Ugandan government that became more relaxed on import laws regarding vehicles older than 5 years old. Within a town center, there are hundreds of people involved in the motorcycle taxi business, including those who own their own motorcycle and those who rent them out to drivers on a weekly basis. The motorcycle taxi drivers (also known as boda boda drivers) offer their services to individuals who need transportation. And, in regards to emergency transport, many women currently use bodas to transport themselves to access medical service centers.

In other places around the world, there have been modifications to motorcycle and bicycle transport options to facilitate emergency transportation. The appendix displays a list of bicycle and motorcycle ambulances that have been utilized in developing countries around the world. Bicycle ambulances have been developed and distributed within Nigeria, Malawi, Uganda, Zambia, Nepal, and India. These systems have been beneficial for communities located within a 5-10 km radius to medical service centers and are more effective for shorter transport distances. Their popularity came in the 1990s when local health epidemics, including Malaria and HIV/AIDS outbreaks put additional stress on healthcare services.

![Figure 7: Bikecart Bicycle Ambulance deployed in Zambia](image)

However, because of the terrain and land use of the Kigezi region, bicycle ambulances are not well suited for emergency transport. The majority of the population in Kabale lives in villages or homes within the mountainous and hilly regions. This creates a much more complex problem, as reaching medical service centers with the resources to address emergency cases are distant for a majority of the population. Unlike bicycle ambulances, there are currently less emergency transportation options that incorporate a motorcycle. These motorcycle ambulances are more expensive than their bicycle ambulance counterparts, but are more adept to transport heavier loads through demanding terrains.

Regardless of the type of motorcycle ambulance, there are several conditions that must be met for the motorcycle ambulance to be able to operate and provide safe travel for passengers. Most of these conditions come down to motorcycle requirements. The power of the motorcycle has to be able to
handle the trailer’s weight and momentum as well as any additional passengers on the back of the motorcycle. There are several conditions that should be met: four stroke engine (which provides more torque and fuel efficiency), near 150-200cc (though a 125cc motorcycle could work if well-maintained), minimum 8 kWatts to pull nearly 350 kg, and a minimum of 15bhp. In the case that the motorcycle does not meet these conditions, there could be damage to the motorcycle, such as decreased fuel efficiency, or inability to meet its expected functionality. In past reviews of motorcycle ambulances, there have been discussions of how the ambulance attachment changes the fuel consumption and operational capacity of the motorcycle. It has been cited that fuel consumption can increase from 5-8 km/liter to 25-30 km/liter when the motorcycle ambulance is driven on rough terrain.

**Motorcycle Ambulance Design Considerations**

The motorcycle ambulance has several key technical considerations to ensure safety and reliability for patient emergency transport. The following section details several of these considerations and discusses their importance, taking into account the design requirements and limitations detailed in the previous section.

**Ambulance Orientation**

There are currently three types of motorcycle ambulances on the market. Each of these products provides something different and is able to address different terrains and environmental conditions. This is because of the change in balance of the vehicle and expanded width of the system.

*Table 1: Orientation Comparison*

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Comparisons</th>
<th>Pictures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Back attachment</td>
<td>Attachment links to the back, similar to a trailer bed or wagon. Person’s orientation can vary facing towards or away from the motorcycle</td>
<td>Advantages: This back attachment is helpful for the driver because it is easiest to control the movement of the motorcycle, as the ambulance is in line with the direction of the motorcycle. Disadvantages: Does not move with the motorcycle</td>
<td></td>
</tr>
<tr>
<td>Side car attachment</td>
<td>Attachment to the motorcycle is on the side of the frame.</td>
<td>Advantages: Carriage moves with the motorcycle Disadvantages: Makes the motorcycle more difficult for drivers to operate; can apply undue lateral torsion</td>
<td></td>
</tr>
</tbody>
</table>
| Three wheel motorcycle ambulance | The back, typically used for carrying cargo, is converted into a carriage for patient transport. | Advantages: Able to transport heavy loads  
Disadvantages: More expensive and less readily available. Typically needs to be custom-made to order. |

The differences between these three types of motorcycle ambulances are not just restricted to their physical designs. There are critical management, ownership, and maintenance considerations that differ between the types of motorcycle ambulances. The differences are most pronounced between those designs that can be easily attached and detached to motorcycles and those that cannot, or those which integrate the motorcycle body in the carriage (similar to the three-wheel motorcycle ambulance). The ambulance attachment model capitalizes on the motorcycle taxi service and the network of motorcycle taxi drivers that already exists. The attachment can be moved between motorcycles and allows more flexibility for drivers, in case drivers need a break due to hours, experience their own emergency situations, or leave the service and there is a need for a new driver. The motorcycle ambulance that does not allow for ambulance carriage detachment requires the availability of a singular driver to provide the service. If the ambulance needs maintenance, the whole model can be decommissioned. This is not the case for the attachment model; if the motorcycle needs maintenance, the ambulance attachment can be removed and transferred to another motorcycle.

**Attachment Selection**
For any trailer system, the attachment, which encompasses both the hitch on the towing vehicle and the coupling joint, is incredibly important to consider, as it affects the stability of the system as well as the navigational capacity of the ambulance carriage.

**Hitch**
The hitch is the mechanism on a motorcycle onto which the ambulance carriage is attached. The hitch itself should be sturdy and connected to at least four non-moving points along the bike (i.e., it cannot be connected to the suspension components or shock absorbers). The hitch should be close to the height of the axle of the rear wheel – any higher, and the rear-wheel will lighten during braking; any lower, and the front wheel will lighten during braking, creating a wobble.xvi

**Coupling Joint**
The coupling joint allows for angular displacement between the motorcycle and the trailer and is an integral part for the functionality and navigational capability of the entire system. As the roads in the Kigezi region are generally unpaved and rocky, common off-road coupling mechanisms were considered. An overview of different off-road coupling joints is included below. In addition to the coupling joint, there should also be a safety chain between the trailer and the hitch in the case of attachment failure.
<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Comparisons</th>
<th>Pictures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball coupling xvii</td>
<td>Consists of a bearing stud and a socket. Used in most automobiles.</td>
<td>Advantages: Allows for movement in two planes at the same time. Generally eliminates backlash (amount of free movement between the rotating parts) Disadvantages: If the cast coupling body is too close to the tongue, the system will not accommodate for much vertical angular displacement between the vehicle and the trailer; require regular inspection for damage or trapped material</td>
<td><img src="image1" alt="Ball Coupling Image" /></td>
</tr>
<tr>
<td>Pintle hook and eye xviii</td>
<td>Pin with locking mechanism that accepts an eye fitting</td>
<td>Advantages: Can accommodate for large trailer weights. Allows for quick hitching/unhitching. Disadvantages: Not much vertical angularity without free-play between eye and pin. Some designs suffer from “kick” and “lag” and are noisy when dragged over rougher terrains.</td>
<td><img src="image2" alt="Pintle Hook Image" /></td>
</tr>
</tbody>
</table>
Poly-block couplings\textsuperscript{six}  
Two swiveling points to allow movements in the vertical and horizontal planes.

Advantages: Fewer trailer “thumps and bumps” are transmitted to the towing vehicle, allowing for a smoother ride.
Disadvantages: Difficult to manufacture locally, and coupling/uncoupling can be tedious

**Tongue and Tongue Weight**
The tongue weight describes the downward force that the tongue of the trailer applies to the hitch of the towing vehicle. Most experts recommend that the tongue weight should be between 9-20% of the gross trailer weight.\textsuperscript{six} Too much weight and the trailer places too much force on the back tires of the motorcycle, which may unweigh the front of the motorcycle, thus affecting the steering and braking of the entire system. However, if the tongue weight is too light, there may be trailer sway. Additionally, during periods of hard braking, the trailer may push onto the motorcycle, causing the back wheels to unweigh.

In order to obtain this tongue weight requirement, many people recommend that the axle width to tongue length ratio should be around 1:1.5-3. This ratio allows for the proper tracking of the motorcycle trailer, as well as maximizes the navigational and turning capabilities of the motorcycle-trailer system.

**Carriage and Canopy Design**
The carriage design is an essential part of the motorcycle ambulance, because it serves as a structural component and is user facing. The carriage must be designed as to be functional, meaning that it cannot be too heavy or bulky for a motorcycle to pull. Furthermore, the design must take into consideration safety, meaning that it must withstand substantial loading and environmental factors and be designed for cases of misuse. Lastly, the design must be tailored for user circumstances and preferences, meaning that its design and interior layout must be friendly for its initial target population of women in labor and other stakeholders such as boda drivers. This section discusses the considerations behind (1) sizing and dimensioning, (2) materials and manufacturing processes required, (3) the design of interior layout and offered functionalities, and (4) the construction of a canopy or overhang system.

Firstly, the sizing and dimensioning of the carriage are driven by the necessary functionality of the product and influence decisions on materials selection and interior layout design. To begin, we considered what the carriage would need to do -- with its main function being to transport women in labor, the sizing was largely driven by the dimensions for stretchers and hospital beds that these women typically lie in while in labor. This allowed us to replicate the dimensions of standard stretchers and consider this as the first minimum requirement for sizing. From online literature and engineering drawings, we were able to deduce that sizing typically varies from 0.5 meters in width to 2 meters in length for products that allow patients to lie down fully. The width of the mattress varies - in order to define this dimension, we visited local markets that sold mattresses and compared them to those available with the maternity ward’s patient bed mattresses. Thus, for the dimensioning of our system, we determined that a width of 0.6 meters and length of 2 meters are required for comfortable
transportation of a patient while extended and lying down. We also considered the option of allowing a caretaker to accompany the patient in the carriage. Depending on how the caretaker is oriented, this would also influence the sizing of the carriage. This, however, would require more space in the carriage, adding weight to the carriage and overextending it further in length or width. We recognized that this might negatively affect the product's ability to be pulled by a motorcycle and obstruct the boda driver's field of view.

Next, we had to consider the materials that would compose the carriage, along with the manufacturing that would be required to produce and join individual parts. Some options included working with steel sheets, steel round piping, steel square tubing, and a combination of each. We had selected mild steel as the raw material for construction because of its availability, strength, and manufacturing ability in Uganda. Additionally, steel is a frequent material selection for automobile and motor vehicle components. In order to join pieces together, the idea of welding metal together, perhaps with the added strength and support of angle bars, was suggested.

Another factor in carriage design was the interior layout and functionalities that would be incorporated into the system. This was driven by information provided by midwives and mothers, along with decisions and justifications made for predicate systems. A recommended feature was to create a reclining bed in order to offer mothers options for positioning while traveling and in labor. Additionally, mothers tend to walk or be carried by stretcher to the ambulance; thus, we wanted to create a system that would be compatible with these different options and allow the woman to comfortably load the carriage. Some ideas included building a stretcher into our transport system such that it can be used to pick up the woman and drop her off. We brainstormed and sketched a series of stretcher-compatible systems, which included sliding and locking mechanisms to place the stretcher into the carriage.

Lastly, we discussed options for a canopy or overhang system. The main requirement for this was to keep the frame as light as possible, while still effective in offering patient privacy and protection from environmental factors such as rain and sun. Tarpaulin was the recommended material for coverage, as it was cheap, effective, and locally available. To support the tarpaulin, we considered steel tubing extending upright along the edges of the carriage and/or at the four corners, along with cross-sections across the top of the canopy to give the frame structure. Bamboo was another option we discussed for the canopy frame because of its light weight, but did not find nearly as locally available, long lasting, or strong.

**Wheels**

The wheel selection, placement, and attachment to the frame are important for a number of reasons. Firstly, they provide the mechanism that will allow the ambulance to trail behind the motorcycle at the same speed. Secondly, they support the majority of the weight of the frame and carriage. Lastly, the attachment mechanism, when considering suspension, can dampen the bouncing movements caused by uneven terrain, which is prevalent in rural Uganda. This section discusses the (1) wheel specifications and load capacity, based on the local available motorcycle wheel market in Kabale, Uganda, (2) the location of the wheels on the frame to evenly and effectively distribute the load of the frame and carriage (when fully loaded), and (3) the mechanism for attaching the wheels to the frame, including the designs considerations.

Motorcycle wheel specifications convey a great deal of information. The specifications include the speed rating, load rating, rim diameter, aspect ratio, and section width. Based on these numbers, it is possible to understand the limitations of the ambulance and the driver restrictions to driving behaviors/mechanisms. In Kabale, Uganda, there few options for motorcycle tires. The Bajaj Boxer
motorcycles that are most commonly used utilize a 3.00 x 17, 45 P – 100/90 x 17, 55 P which conveys that the wheel capacity is 165 kg and 218 kg, respectively.xx

The axle, and therefore the wheel, location on the frame should be selected to balance the load effectively. In many cases, experts advise that the axle location should be behind the center of the load. The tongue of the frame and hitch combination can handle 15% of the carriage load and therefore the axle location can be farther along the frame location.xxi

The wheel connections not only detail the connection between the wheels and the frame, but also serves as the suspension system of the attachment. The suspension system is especially important for emergency transport in the Kigezi region because of the unpaved roads and the hilly terrain. Together, these two factors can increase the discomfort for the ambulance passenger. Adding suspension to the attachment can dampen the vibrations and movements of the attachment as it passes over rough terrain.

Table 3: Wheel Connection Comparisonxxii

<table>
<thead>
<tr>
<th>Connection</th>
<th>Description</th>
<th>Comparisons</th>
<th>Pictures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single axle</td>
<td>Allows for separate suspensions for each wheel. When additional stress is</td>
<td>Advantages: most common, minimizes stress on frame, load is</td>
<td><img src="image1.png" alt="Single Axle Picture" /></td>
</tr>
<tr>
<td>leaf springs</td>
<td>applied to a wheel, the curved strips are able to assume part of the load</td>
<td>distributed on 4 points on the frame, easy to set-up</td>
<td></td>
</tr>
<tr>
<td></td>
<td>without pushing up on the frame.</td>
<td>Disadvantages: does not account for wheel side-to-side movement</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Torsion axle</td>
<td>Rotational piece connects directly to the center of the wheel via the axle</td>
<td>Advantages: compact, good fit for low bed height (the attachment does not</td>
<td><img src="image2.png" alt="Torsion Axle Picture" /></td>
</tr>
<tr>
<td></td>
<td>and does not raise the bed farther from the center of the wheel. Instead,</td>
<td>raise the bed farther from the wheel)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>the mounting option is connected to the rotational piece and lifts the</td>
<td>Disadvantages: meant for light duty trailers, loading to the frame is</td>
<td></td>
</tr>
<tr>
<td></td>
<td>frame.</td>
<td>complex, difficult to find the rotational piece, no wheel side-to-side</td>
<td></td>
</tr>
</tbody>
</table>
### Spring axle

Spring is attached to the mounting option and then to the underside of the frame. When the wheels are attached to the perimeter of the frame, the spring system does not have to elevate the frame.

### Advantages:
- Easy mechanism, high bed orientation

### Disadvantages:
- Difficult to mount, must be maintained appropriately, spring can be less durable than other options

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**Pulse: Locally Available Motorcycle Ambulance**

Through our research, we found a current motorcycle ambulance system that is being fabricated in Kampala and distributed throughout Uganda. Pulse, a social enterprise, started its operations in 2011 after the founder Daryl Funk left Zambikes to start a motorcycle ambulance company in Uganda. Since its beginnings, Pulse has developed three separate motorcycle ambulance options (reflecting the three design options described previously), distributed over 300 systems, and developed partnerships with private and public parties. They have worked hand-in-hand with communities to distribute as well as build sustainable demand models that meet the costs of operating and maintaining the motorcycle ambulance. Upon learning of Pulse, we traveled to Kampala to meet with the team and their founder. During our meeting we learned more about their design process, product delivery, business model, and operations and manufacturing processes. After that meeting, we arranged for a motorcycle ambulance to be sent to KIHEFO so that we could continue building a relationship between Pulse and KIHEFO. There were several reasons for having the Pulse motorcycle ambulance at KIHEFO for a few days. During the few days the Pulse system was in Kabale, we were able to conduct interviews with motorcycle drivers and potential users and observe the system performance in the Kabale terrain. We proposed that as part of their trip we would provide (1) a business model for deploying the product in Southern Uganda, including a study on current community payment systems, (2) identification of potential product changes to fit the local needs of the people in the Kigezi region, (3) suggestions on organizations for future partnerships, and (4) awareness of the Pulse company and product in communities across Southern Uganda.

**Task 3: Improving Motorcycle Ambulances for Application in Kigezi, Uganda**

As part of this task, planned a prototyping process to better understand how potential users enjoyed and sought to modify the motorcycle ambulance service. This process involved identifying design requirements and constrains, understanding availability of local materials and processes, designing and constructing a prototype, and getting and evaluating feedback. Because of the characteristics of the Kigezi region, it was important that we introduce the motorcycle ambulance service to prospective customers and ask for their input.
Design Requirements and Constraints

Defining the design requirements and constraints were important for us to systematically evaluate improvements to existing motorcycle ambulances. This also allowed us to formalize criteria for emergency transport systems based upon our needfinding results and prior research.

The requirements are as follows:

- Easily cleanable/hygienic
- Vibrations minimized
- Horizontal movements/effects from turns, brakes, and acceleration minimized
- Protection from environmental elements (e.g. weather, motorcycle exhaust)
- Balanced
- Patient privacy
- There is space for driver, patient, and additional passenger(s)
- Lightweight design (to promote fuel efficiency)
- Capital cost is affordable
- Durable materials and design
- Comfortable interior design (bed, additional materials)
- No sharp edges, points, or hazardous components
- Safe connection mechanisms

The constraints are as follows:

- Power of motorcycle engine
- Dimensions of motorcycles/roads
- Cost
- Availability of manufacturing, repairs, and parts
- Driver skill
- Team skills and knowledge

Locally Available Materials and Production

One main consideration for any motorcycle ambulance design is for the product's materials to be locally available and parts locally repairable. Additionally, production and maintenance should be compatible with local manufacturing processes. In order to ensure this, we conducted an assessment of locally available materials and production methods in Kabale, Uganda and interviewed local engineers and mechanics.
During our conversations and research, we were able to find and price many standard motorcycle parts were available at local motor vehicle repair shops and small vehicle shops, including wheel tubing and frames, gears, suspension, shock absorbers, and headlights. These parts are typically prefabricated and imported to ensure proper maintenance and repairs are possible for local boda boda drivers and motorcycle owners. Besides prefabricated parts, raw material is also plentiful in Kabale. For metals, these include mild steel tubing and piping of several dimensions and gage thicknesses, steel sheets for sheet bending and cutting, along with galvanized iron piping, tubing, and sheets. Furthermore, wood is readily available in Kabale, with numerous woodworking and furniture stores contributing to the demand for wood. Lastly, plastic sheets and tubing were also available in the local markets. The most commonly found manufacturing processes included welding, drilling, tube and pipe bending, sheet metal work, woodwork, and usage of hand tools to form raw materials, such as files and hammers.

While available in Kabale, all of these parts and processes are also available in larger quantities and varieties in Kampala, the capital and biggest city in Uganda from which many of these materials are transported.

**Prototyping and User Feedback**

We decided to build a prototype of the ambulance carriage in order to gain more accurate responses in our willingness-to-pay study and to find potentially unmet needs from prospective customers and users of the ambulance service. Constrained by time and resources, our team wanted to focus on two specific questions:

1. Is the motorcycle ambulance carriage comfortable and equipped with enough functionality?
2. Would expectant mothers be willing to pay more to use the motorcycle ambulance for transport to a medical services center at the onset of labor?

Because of the specificity of these questions, we decided to test the comfortability of the space of the carriage, instead of constructing a prototype with full functionality. By creating a product that our interview respondents could see and physically interact with, we hoped that our respondents would (1) have a clearer image of the service, (2) be more forthcoming and accurate in their estimates for how much they would be willing to pay for the service, and (3) comment on any features or conditions that
were needed in terms of comfort and operations. Several of the principles we followed during the prototyping process include adaptability, local resources, flexibility, cost effective, and temporal. For a portion of the potential customer interviews, we were able to procure a Pulse motorcycle ambulance and replace the prototype with the actual motorcycle ambulance.

**Design**

One of the purposes of the prototype was to test the comfortability and space of the ambulance attachment. Therefore, our team decided to focus on creating a set of products that would approximate an ambulance carriage that is currently on the market to test the size, comfort, and ease of entry. To test these factors, we decided that the prototype would consist of three main parts – the bed, the canopy, and a frame to model as the “reclining” feature of the mattress.

An evaluation of local materials was conducted to determine which materials were widely available and could be used for our prototype. Based on the availability and costs of locally available materials, the team decided to use wood and PRR pipe for the bulk of the prototype. A foam mattress was obtained for the prototype.

To create the canopy and frame for the bed, 22 PRR tubes were cut to varying lengths. Ten tubes were used to create the bottom rectangular frame. Eight tubes (four on each long side of the rectangular frame) were placed vertically on the longer sides. These poles gradually increased in height, creating the sloping curve of the canopy. The last four tubes were placed on the top of the structure, held up by the eight vertical pieces, in order to hold the structure together. Finally, a tarp was secured over the structure and glued to the bottom frame, completing the canopy imitation.

The reclining feature, on the other hand, was designed simply to showcase the reclining function of the system. As such, we decided on creating a simple wooden right triangle from a single piece of 1inx4inx10ft wood, where the mattress would rest on the hypotenuse of the frame.

The team considered and rejected a number of ideas for elevating the prototype and mimicking the height of the ambulance carriage. For instance, the team discussed placing the prototype on top of dining room tables, but this was rejected as they were deemed too high for mothers to enter without excess strain. It was also suggested that side tables (approximately 3ft by 1ft) be used. However, they were very small, so multiple tables would have to be used, which would be cumbersome to transport. Finally, the team discussed creating a simple wooden frame. Because of the limited time and resources delegated for prototype construction, the elevation of the prototype was created by layering two medical purpose mattresses.

**Construction**

The final prototype consisted of four parts (canopy, mattress, reclining structure, and frame) and took two days to construct. The construction process for each part is outlined below.

Canopy: The final canopy dimensions were approximately 1m x 2m x 1m. The canopy was constructed using 0.5 inch diameter PRR pipes, T-joints, elbow joints, PVC cement, duct tape, and a single piece of 1x4 meter tarp. The bottom rectangular frame was constructed using ten pieces of PRR tubing, with the eight smaller pieces used to construct the longer sides. The sides were connected by elbow joints, while the side pieces were connected with T-joints. Initially, we attempted to use a combination of PVC cement and duct tape in order to create stronger and more stable joints – however, it was found that the cement dried too slowly and was not suitable for ensuring stability. Therefore, duct tape was used exclusively on the remaining joints. In order to maximize the PRR we had remaining, we decided to construct only three heights for the vertical pieces for a total of six PRR pieces total. The tallest was
attached the one end of the frame, the second tallest at the first T-joint from the tallest end, and the smallest pieces were attached at the third T-joint of the bottom frame. We had also planned to superglue the tarp onto the frame, but it was later decided the prototype would be easier to transport if the tarp were detachable. Therefore, the tarp was attached to the frame using tape. We also added one additional wooden block behind the tallest supports in the canopy frame to ensure the tarp stayed taut throughout the testing period. Finally, the sides of the canopy structure were left uncovered by tarp, so that interview participants could easily get in and out of the structure.

Mattress: A simple foam mattress was bought in the Kabale marketplace. The plastic wrapping (that is meant to protect the fabric from getting dirty) was kept on the mattress to ensure ease of cleaning. Additionally, a cloth covering was added during the testing process to ensure cleanliness of the system.

Reclining structure: The reclining structure was constructed from 6 pieces of wood (1 inch thick by 1 foot width), three different nail types, and a few pieces of metal sheet used to bind wood pieces together. The angle at which the reclining block was built was determined by assessing the comfortability of the mattress inclination at different angles. Once the angle was determined, the wooden pieces were fit to the angle. The wooden pieces were nailed together in at least two places, with some pieces bound together using nails and strips of metal sheet. Wood glue was used initially, but, due to the dampness of the wood, this was deemed ineffective.

![Figure 9: Construction of the Reclining Structure](image)

Frame: Upon arrival at the maternity clinic on the very first day of testing, we realized that the ward had a number of thick unused medical mattresses we could use to create a pseudo-frame in order to test the height of the system. We stacked two mattresses of approximately 20 cm width and placed the entire prototype system on top of the two mattresses.

Prospective Customer Feedback
The prototype, and later the Pulse system, was an integral part of the interviewing process. Participants were invited to look at and sit in the prototype as part of the willingness-to-pay interview. Each participant was asked a number of questions regarding their thoughts of the prototype, the comfortableness of the space, and any features they would like to see added to the system. Four separate stakeholder groups (mothers, boda drivers, midwives, and community leaders) were
interviewed as part of the prototyping testing process. Each stakeholder group approached the system with their own biases and perceptions, and subsequently was able to provide unique feedback. Thus, the feedback is grouped according to stakeholder classification. Community leaders are not included in this feedback section as the comments they gave were related more to community payment systems; as such, their comments are included in a later section under the results of the willingness-to-pay study.

![Figure 10: Using the Prototype during Interviews](image1)

![Figure 11: Using the Pulse system during Interviews](image2)

**Mothers**

Most mothers were pleased with the system, finding the space to be very comfortable. Despite the general approval of the prototype, the mothers noted several potential changes to the system:

- Room for luggage: most mothers bring items, such as bedsheets, extra clothes, a basin, and food, with them when they deliver
• Extra guard rails or grip bars that they could hold on to in case the ride was bumpy or they were in pain
• An extra step so that she could get into the prototype more easily.

Figure 12: Household Interviews with Mothers

Figure 13: Field Interviews with Mothers

Boda boda drivers
The local boda boda drivers were generally very receptive to the idea of the motorcycle ambulance. The feedback we received from this stakeholder group fell into two major categories: concerns or suggestions regarding effects of the ambulance attachment on the navigational efficiency of the motorcycle, and comments regarding past emergency transport trips they had given. During the majority of the interviews with boda boda drivers, the Pulse system was available. This provided an accurate representation of the motorcycle ambulance system to be tested by attaching to a motorcycle.
Ambulance and Motorcycle Efficiency: Nearly all boda boda drivers we interviewed were concerned with the stability of the system, and many of them asked if Pulse’s one-sided attachment to the motorcycle affected balance during transport. The majority of the boda boda drivers we interviewed expressed a belief that the system would be very hard to balance, particularly when turning, traveling on inclines/declines, starting the motorcycle, or transporting during the rainy season. The last concern is very valid within the Kigezi region because of the length and intensity of the rain season. The drivers spoke about their current experiences driving in the rain, in which they suspected that the back attachment may be more likely to slip. One driver pointed out that if the speed of the motorcycle was too high, the carriage may be pulled from side to side by the wind. Many of them asked if the motorcycle would be powerful enough to pull the system up mountainous terrains, especially if they were carrying an additional passenger on the motorcycle behind the driver as well as a patient in the carriage. A few boda boda drivers were concerned that the attachment may obstruct their rear view mirrors, and suggested that the rear view mirrors should be extended to be longer. Almost all of the boda boda drivers we interviewed wanted to add light indicators at the back of the carriage to signal braking and turning. A few drivers also wanted a braking system in the carriage for sloped areas. Many asked if spare parts could be easily accessed in case the carriage attachment needed extra repairs or maintenance.

Patient Experience: A few boda boda drivers expressed concerns about the patient experience of the motorcycle ambulance. One boda boda rider was happy to see that there was enough space for the caretaker to ride on the motorcycle – however, he was worried that the caretaker would be located too far away from the patient, and that the patient may be isolated during the journey. Should the patient’s condition worsen along the way, the driver pointed out, the driver and the caretaker may not realize or be able to help until they arrive at the health facility. He suggested adopting a method of easily monitoring the patient’s condition from the front of the motorcycle. One driver suggested that windows be added, so that the patient could see where they were, as well as a light inside the carriage so that it would not be too dark. Another request that was brought up in these interviews was a way of holding the canopy up, so that it did not have to be manually held in place as patients entered or exited the carriage attachment (as the canopy component is moved by lifting the bottom frame of the canopy and does not remain upright without support, usually from a person). One driver insisted that the foot
guard, located at the foot of the bed in the carriage, should be higher, so that the patient does not slip forward in the bed when the motorcycle and ambulance system are traveling down a slope. Other small suggestions included adding more supports on the sides for the safety of the patient as well as creating a stronger canopy so that it could withstand harder rain.

Midwives
The midwives were generally excited about the system, finding the space to be most comfortable. However, a few major concerns were raised, both about the prototype and the Pulse system. For instance, one of the midwives pointed out that it was recommended that some mothers lay on their sides while being transported, and that the safety straps were only long enough to wrap around women who lay on their backs. There were also some concerns that there was not enough space for a caretaker to also be transported during a referral journey. A midwife must accompany a woman to the hospital after being referred from the clinic in case any complications arise. For example, in the case of preeclampsia, the mother’s vitals must be checked every 5 minutes by a midwife. Although the midwives agreed these were rare cases, they argued that these cases must still be accounted for, and that in the current Pulse system there was not enough room for both a midwife and a patient in the carriage area should the ambulance be used for these specific referral journeys. Other additional features the midwives wished for included a hook for an IV drip bag and a space to keep “mama kits”, bags that contain all of the necessary items should a woman need to deliver along the way.

Having the prototype and the Pulse motorcycle ambulance available during prospective customer interviews provided valuable information. In general, interviewees were enthusiastic about the product, although nearly all of them expressed other desires or concerns regarding the carriage. Most mothers wanted more room for their bags if they were to use this service when delivering. Many boda boda drivers were concerned with the stability of the system, and expressed a wish for attachments on both sides of the motorcycle in order to ensure balance. The midwives of the KIHEFO maternity ward were very concerned about the location of the caretaker should the ambulance be used for referral journeys.

Task 4: Creating a Business Model for Providing Motorcycle Ambulance Service in Kigezi, Uganda
Despite the undeniable need for promoting, developing, and distributing these systems throughout Kabale, Uganda, and the developing world, it is important to understand the management and business of providing and running a successful and sustainable motorcycle ambulance service. In many cases, the population that is most impacted by poor, inadequate, or inaccessible medical services and maternal health services, is also the population that is unable to afford transportation fees. Therefore, developing a more cost effective, safe, and quality motorcycle ambulance only addresses half of the problem. The prospective KIHEFO motorcycle ambulance service provides expectant mothers safe transportation to a hospital or clinic setting in a timely fashion so as to limit possible complications with child delivery. The KIHEFO motorcycle ambulance service is meant to serve as a proof of concept and a marketing tool for communities and villages to buy a system and provide the service for their community members.

Currently, it is difficult for individual communities and villages to provide expensive communal services for their community members. Despite this barrier, there are several key community factors that KIHEFO has tapped in to that can be utilized in the distribution model. Firstly, communities have a strong presence of groups, in which individuals form community organizations for a specific purpose. Some of these groups, such as the ngozi group, provide a transport service for pregnant women via stretchers so that they can be safely transported from their houses to a road. Secondly, KIHEFO’s
relationships with these communities can provide a basis for helping to fund the capital expenses for the ambulance service. Thirdly, KIHEFO has a referral system where women who are admitted to the maternal clinic for delivery have free referral services to a local hospital if there are complications with the delivery. While the KIHEFO ambulance is able to provide service between the KIHEFO clinics and the hospital, there is currently limited infrastructure to allow the ambulance to travel back and forth between communities/villages, the clinic, and the hospital. There are several reasons for this, as articulated in the Needs Identification section.

Customer Acquisition and Relations

Through observations and extensive interviews with midwives, traditional birth attendants, and mothers, we have found there is a need for reaching customers through a variety of ways. Currently, there are several ways that KIHEFO reaches potential customers: outreaches, in-patient services, and relationships with community groups (such as religious groups) and other health service workers such as traditional healers and traditional birth attendants. Although expectant mothers are the first customer segment that this service is meant to provide for, there is great potential for using the motorcycle ambulance service for transporting injured and ill individuals. KIHEFO has built relationships with at least 10 communities throughout the Kigezi region and has continued to foster these relationships through continued communication.

KIHEFO has established a network of communities and villages in which they currently work. Along with USAID, KIHEFO will be rolling out a new insurance policy in the fall of 2016 in which the motorcycle ambulance will become a part of their included services. KIHEFO will be partnering with 10 communities within the Kigezi region to provide health care resources. Basic insurance (UGX 30,000 per person per year) will include outpatient services such as access to weekly outreaches that provide HIV/AIDS, maternal health, general health resources for individuals, and regular visits to the clinic in Kabale town where individuals are not admitted for overnight stays. Full access insurance (UGX 50,000 per person per year) will include both outpatient and inpatient services as well as transportation expenses for emergency situations and women in delivery. As part of the insurance program, every individual in the household would be required to subscribe to the insurance. Therefore, a family of 8 would be required to pay UGX 400,000 in a year for full access insurance. Because KIHEFO caters to low income and poor families within the Kigezi region, they understand the financial limitations of families in the area. As such, KIHEFO provides an array of programs that address community development and financial development. One program that is seen as a way for families to increase their household incomes is through rabbit breeding and distribution. As compared to other livestock in the Kigezi region, rabbits do not require specific feed and reproduce at a higher rate. It is estimated that a percentage of the total monthly insurance revenue will be directed towards the motorcycle ambulance service.

Service Components

To provide a motorcycle ambulance service, it is important that there are key individuals and infrastructure in place. The different parts of the service include the ambulance attachment, motorcycle, driver, and call center.

1. Ambulance attachment: Recently, KIHEFO has established a relationship with Pulse, a Kampala, Uganda based company that manufactures and distributes motorcycle ambulance products. Pulse also provides maintenance for their products and training for drivers.
2. Motorcycle: The motorcycle is equally as important as the ambulance attachment. Motorcycle details have previously been addressed in Task 2.
3. Driver: The driver is a critical part of the service, as they are responsible for setting the service price, maintaining the motorcycle and ambulance attachment, and providing safe and efficient
transport for customers. This last point becomes crucial because of the additional skill it takes to drive a motorcycle with a 200kg (or more) attachment. Given the hilly landscape and unpaved community roads in Kabale, Uganda, the driver must be familiar with the terrain and be able to adjust quickly to ensure that the customer has a safe journey. Although motorcycle ambulance attachments on the market have been tested for almost all conditions and the safety ratings are usually listed at below the failure limitations of the motorcycle and ambulance attachments, there is no substitute for a good driver who respects and maintains his/her motorcycle and ambulance attachment.

4. Communication network: There will need to be an individual who is able to accept calls from prospective customers, detail their condition, and dispatch the driver in a timely manner. In cases in which the service is small, it is possible for the driver to act as the call center, receiving calls from patients and driving to pick them up. In cases in which the service is large and expands to many different communities, there is a greater need to have a call center that receives calls from patients and directs the driver where to go and when to pick up the patients. Mobile phones are commonplace in Uganda, regardless of socioeconomic status. Therefore, it is possible for the call center to be a main component of managing the service. Additionally, the availability of mobile phones amongst customers is an advantage for the service. In addition to facilitating communications between patients and the driver (and the call center), the mobile phones can be used to send mobile money to the driver (and the call center). Mobile money is commonplace in Uganda and provides an easy way to transfer funds to and from individuals and aid with accounting purposes, as there is a receipt upon finalizing each transaction.

Financial Model

In addition to understanding the motorcycle ambulance service components, the customer analysis and pricing models must make this service accessible for those who need it most. As part of our research, we set out to understand the demand, current use, and pricing of emergency transport systems. The following section details several different business models that can be implemented to ensure that a motorcycle ambulance service is sustainable. A sustainable business model is characterized by a financial model in which the revenue stream is able to meet or exceed system costs. The three basic models below provide a foundation for understanding how to establish and manage a motorcycle ambulance system. Each model is unique and will be successful in different situations.

The first model is a pay per ride model, in which a customer pays for the service of the motorcycle ambulance when they need to use the service. This is very similar to the type of service that is currently offered by motorcycle taxis in Uganda. When an individual requests transport to a certain location, they find a motorcycle taxi, negotiate a price prior to embarking, the driver provides the service, and the customer pays the negotiated price. The price for the service, based on our conversations with motorcycle taxi drivers, varies depending upon the time of day, distance, and income of the customer. In the case of the motorcycle ambulance, the same process would occur. There may be slight variations for the customer. For example, the customer will have access to the driver’s phone number (this may in later stages become a call center that handles a network of motorcycle ambulances) and calls the motorcycle ambulance when transport is needed. Similar to traditional motorcycle taxi service, the motorcycle ambulance (attachment) may be rented or owned by the driver. To account for the capital cost of the attachment, the additional gas and maintenance expenditures, the motorcycle ambulance driver may increase the price of the transport service.

The second model is an insurance model that takes advantage of community group savings and community health schemes. These programs operate similarly to a health insurance system in which many households, families, or individuals enroll in the insurance program and pay a monthly or annual
fee to be included in the system. All of those that are enrolled in the system receive predetermined services when they are needed. In the case of motorcycle ambulance services, any individual who is enrolled in the health insurance system would receive the ambulance service for free or a highly subsidized rate. Enrolled individuals would contact someone within the motorcycle ambulance service or insurance system to procure motorcycle ambulance transport. The individual would have a card that would identify them as an enrolled individual, or the insurance system would take responsibility for identifying the individual as part of the health insurance system. The size of this system would be dependent upon the insurance rate and the number of enrolled individuals. In this case, there are two ways that the service operations receive revenue. The most common form for the insurance model is for the insurance service to pay the motorcycle ambulance service a percentage or specific amount every month for the service. The other form is for the insurance service to pay the motorcycle ambulance service a specific amount for each ride that is given for an individual enrolled in the program.

The third model combines the insurance and pay per ride models in case the service is made available for individuals who enroll or do not enroll in the associated insurance program. In this case, it becomes even more important for individuals who are enrolled in the insurance program to have identification cards (or other means of identifying an individual within the insurance program, which could be the responsibility of the call center) to let the driver know that they will not be paying at the end of the ride for the service which has been provided. Additionally, it is important to accurately price the system for non-insurance customers so that the driver or call center manager does not underserve a type of customer to make a profit for the service. This becomes a critical concern when a lower revenue making customer is surpassed for a higher revenue making customer who is in a less critical condition.

Table 4: Summary of Pricing Schemes

<table>
<thead>
<tr>
<th>Description</th>
<th>Revenue Streams for Financial Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pay per Ride</td>
<td>Ride Fee</td>
</tr>
<tr>
<td>Each customer pays a ride fee (this can be either a flat rate or vary based on the distance traveled)</td>
<td>✓</td>
</tr>
<tr>
<td>Insurance</td>
<td>The insurance company pays the service providers a set amount every month or a set amount per every ride given</td>
</tr>
<tr>
<td>Combined: Pay per Ride &amp; Insurance</td>
<td>Combination of the two previous models where the service provider earns revenue by giving rides to customers not on the insurance program and also receives revenue through the insurance program</td>
</tr>
</tbody>
</table>

*Subsidy refers to a donation that can occur when the system originally starts (or at a periodic interval) or can occur based on the number of rides that are given.
Willingness to Pay Study

In order to establish a sustainable model for integrating the motorcycle ambulance carriage into communities for delivery transit use, it is essential that we gauge how much communities are able and willing to pay for these services. One way in which we can understand what an appropriate price for the ambulance services would be is a willingness to pay study.

WTP survey data allow us to ‘estimate the number of clients who will pay a given price, the amount of revenue that will be generated by that price, and if the appropriate questions are included in the questionnaire, the characteristics of individuals who will or will not pay that price’\textsuperscript{xxii}. In other words, willingness to pay (WTP) studies can be used to understand how much a community or sample set would be willing to pay for a given service (keeping in mind different socioeconomic standings exist) and determine demand curves (relating the percentage of people interviewed to the maximum price they would be willing to pay), among other things. In our case, we can analyze WTP responses to predict the optimum price at which motorcycle ambulance carriages can be offered while being affordable to individual mothers as well as sustainable to the community as a whole. After all, it is critical to keep in mind that, the challenge for social programs is to set prices low enough to be affordable to the target clientele and yet high enough to avoid cannibalizing self-supporting, fully commercial brands and services\textsuperscript{1}. Additionally, the WTP survey will supplement the financial and business models for the ambulance systems, allowing for more informed decisions when integrated into communities.

Design of Study

Our WTP study was based on interviewing (both current and expecting) mothers, arguably the most important stakeholders in the motorcycle ambulance integration and implementation processes. Community leaders and boda drivers were also interviewed to obtain a holistic understanding of the price and societal dynamics that are likely to play out if a motorcycle ambulance were to be introduced to a community. Our interviews with community leaders helped us understand different mechanisms for pooling and sharing resources, one of the primary models being considered for the ambulance integration process. Additionally, interviewing boda drivers provided us with critical information regarding the anticipated running costs of using the motorcycle-powered ambulance, a general idea of how the carriage is perceived (with regards to functionality and navigation ease) among people who drive motorcycles everyday, as well as the average costs for hiring a motorcycle without the carriage.

The questions for the WTP survey were created and finalized with several notes in mind. They serve several purposes, such as helping us to determine the socioeconomic standing of the mothers (which would guide us in understanding the rationale behind the price quotes they gave us), and to understand any social, cultural or economic barriers to seeking supervised medical care (‘3 Delays model’, as explained in the transportation barrier section). There were numerous sets of sub-questions that varied depending on which of the three target groups we were addressing (The questions are present in the appendix).

With regards to the core of the WTP survey, however, we posed questions according to the following categories

1. Introduction: This section encompassed the mother’s name, age and home location
2. Ability of female to make decisions: These questions helped us understand how much of a say the mother had in household matters. Additionally, income and saving values were particularly useful in understanding the financial circumstances of the mother and her family, and by extension, her economic standing in her community.
3. Availability of transport: This section helped us understand how ubiquitous different bodas (and other transport means) were in the home community of the mother, her inclinations and
disinclinations to bodas, how much she usually pays for boda rides (to juxtapose the price of regular commutes to an ambulance transits), and her previous experience with emergency transport options (once again, for comparison purposes).

4. Community groups: The questions in this category were aimed at gaging the mother’s social standing, whether she was in a community support system of some sort and what kind of reinforcements the group provided (for example, whether emergency transport or health issues’ charges were covered). They were also directed to aid our understanding of how inclusive (or exclusive) community groups were (something crucial to know, given that the motorcycle ambulance would be a shared resource if procured by a community, and would need to be integrated in an inclusive system).

5. Birthing experience: This was one of the more important categories given that it dealt directly with the birthing process and the mothers’ personal experiences and encounters with problems (if any) with transportation during the delivery/referral transits. This served as the problem scoping space and paved way for the introduction of the motorcycle carriage.

6. Prototype categories: Questions here were concerned with user feedback (with regards to the prototype and the actual motorcycle carriage) and suggested recommendations. The three most important questions, however, were the pricing questions trio: 1. How much would you be willing to pay for this mode of transport to the health centre during your delivery transit? 2. Would you be able to pay for this mode of transport if the price were UGX 10,000 more (than the previously recorded answer)? 3. What is the maximum amount you would be willing to pay for this ambulance service? These questions served as the pillars for the demand curve (the two prior questions culminated in the asking of the third question, which was used to draw graph 1 below).

Methodology
Interviews for the willingness-to-pay study were conducted between September 8, 2016 and September 15, 2016. Survey questions were created for each potential “stakeholder”, namely, mothers (both those expecting and those who had already delivered), boda drivers, and community leaders. A total of 46 formal interviews were conducted, 35 of them with local women, 8 with local boda drivers, and 3 with community leaders. The interviews were conducted in town, at KIHEFO’s maternity ward, and in three villages in the Kabale region. These interviews were conducted in Rukiga, the local language, with some partially conducted in English – KIHEFO staff members provided translations for the Stanford team and interview participants. Interviews ranged from 30 to 60 minutes long and were generally conducted by two or three Stanford team members: one member to ask questions, and at least one member to record responses. The same list of questions was posed to all participants of their respective “stakeholder” classification, though the Stanford team would ask clarifying or probing questions after some responses in order to gain a better understanding of the individual’s life experience. Topics covered in these interviews included occupations, monthly income and savings, community groups, and experiences with birth. Upon the completion of these questions, the participant would be invited to sit in the prototype/Pulse system. If the participant was classified as a “mother”, she was then asked a series of questions about the prototype (e.g., in comparison to other transportation options, or any additional features they wanted to see), as well as some questions regarding the price she would be willing to pay for this service. If the participant was a boda boda driver, they were asked about any concerns they may have about towing the prototype behind their motorcycle, as well as how much they would charge patients if they were to own one of these ambulance attachments. Community leaders were asked to explain the steps the group may take in order to obtain one of these systems, including the allocation of services amongst members after purchasing one of these systems.
One informal focus group was also conducted at the village of Kasinda with approximately 9 local women. This focus group attempted to gauge local perceptions and concerns for the product. It also attempted to gain a general estimate of the price the community would pay for a single ride in the motorcycle ambulance to the hospital.

**Results**

The maximum amount the mothers would be willing to pay for the ambulance service varied upon the distance between their homes and the health center of their choice. In order to normalize the price quotations, we divided the maximum amount willing to pay of each person by the distance they stated to the health center. Therefore, the normalized unit is UGX (Ugandan Shilling)/km. The following demand graph is indicative of the results we obtained for the maximum price quotations (normalized).

![Graph 1: Graph showing the proportion of the sample willing to pay different maximum prices (per kilometre) for the motorcycle ambulance, for the delivery transit.](image)

As can be noted from the graph, it follows the conventional downward slope of most demand curves. WTP surveys undoubtedly have their limitations, as do the results that can be drawn from them. One such shortcoming is that ‘the potential range of prices (for the demand curve) may be quite broad, and there is usually no optimal price for a program to charge’\(^1\). Keeping this in mind, using different supply curves (depending on the carriage production rate and the supplying company) is again another possible avenue for further understanding the dynamics of motorcycle ambulance integration into societies.

Another graph worth considering is as follows:
This graph displays the trend between the maximum price mothers would be willing to pay for the ambulance services against the distance from their homes to the health center. As can be seen from the trend line, as the distance from the health center increases, the less people are willing to pay for each kilometer travelled in the motorcycle ambulance. This is quite an understandable observation since there are limited budgets within which people must carry out functions, including those pertaining to health care. The line of best fit follows a polynomial progression and can be represented by the equation: \( y = 56.249x^2 - 1698.9x + 13823 \).

One of the biggest challenges was sensitizing the interviewees to the nature of the study; it was critical that we reiterated the WTP question trio was not offering a stage for bargaining but rather a platform for understanding the maximum price the ambulance services that could be offered. One of the ways in which we went about ensuring that it was not a bargaining system was, prior to asking the trio of questions, we explicitly stated that there was a calculated price for the ambulance services (UGX/km) and the interviewee’s responses would not affect that undisclosed price. The notion of a fair price was also elucidated to reinforce the importance of the symbiotic relationship between affordability and sustainability.

The willingness to pay a certain price for a certain product is contingent upon numerous factors, the most important being financial circumstances. Another indicator worth considering is the ability to pay, given that it directly extends from the mother’s economic circumstances and will ultimately define whether she will be able to go forward with the transport service or not. This is one possible avenue for future analysis.

There were indeed numerous limitations that existed and assumptions made during the course of this study. Firstly, our sample set was not random but rather interviewed mothers who were affiliated with KIHEFO in some way or another (either maternity ward patients, members of one of KIHEFO’s partner
communities etc.). Additionally, the interviews required translators and as in any translation process, it is difficult to ensure that the original nature of the question remains through translation. Furthermore, our sample set was confined to 33 mothers (35 were interviewed, 2 of which were not able to provide ample information and could not be considered for analysis), particularly due to time limitations. With regards to assumptions, if a mother was unable to state her earnings as distinct from her household’s but contributed equally (with respect to her husband) we assumed that her individual earnings would be half of that of the household, for the sake of simplicity.

Keeping these limitations aside, the interviews provided us with a vast understanding of the current state of healthcare based transportation in and around the Kabale region. The interviews we conducted enabled us to converse with mothers from different backgrounds and different walks of life. Learning that health care is given great consideration amongst the vast majority of the mothers we interviewed was undoubtedly one of the highlights, and their excitement over the motorcycle ambulance made our experience exponentially more fulfilling.

Conclusion
This report details our team process for helping KIHEFO understand, consider, and implement a motorcycle ambulance service for addressing maternal healthcare in the Kigezi region. This report is accompanied by a financial model that will help KIHEFO continue moving towards a motorcycle ambulance service.

Although this report is meant to help organizations like KIHEFO, as well as communities, better understand emergency transport solutions, we hope that this report will be educational for other students who are interested in tackling problems in global development and sustainability. As young engineers, this has been an incredible opportunity for us to learn about the potential for innovations to alleviate problems in an international environment, along with the considerations that must come along with them. We strongly believe that other students - engineering or of other disciplines - will be able to learn from our experiences and build upon and improve our work.

Moving Forward
As part of the plans to bring a motorcycle ambulance to KIHEFO and the Kabale district, the Stanford SSLP team has created a crowdfunding campaign that will allow KIHEFO to raise the necessary funds to obtain a motorcycle ambulance through Pulse and begin to provide emergency transport to expecting mothers. This service will first be introduced to the Kabale district through KIHEFO before local communities and villages obtain their own motorcycle ambulance units to more efficiently provide emergency transport to community members. The crowdfunding campaign goal encompasses an amount to (1) purchase an ambulance attachment, (2) purchase a motorcycle (boda boda) strictly for the purpose of emergency transport, (3) a canopy that will protect the motorcycle driver from the elements (which will be especially useful during the wet seasons, where rain can prevent drivers from taking customers long distances), (4) part of the monthly salary for a full time driver and a call center that will receive emergency phone calls and deploy the motorcycle ambulance as fit, and (5) training costs for the motorcycle driver.
Stanford 2016 SSLP Maternal Health Team

The Summer Service Learning Program (SSLP) is an opportunity sponsored by the Stanford School of Engineering's Global Engineering Programs. Through SSLP, Stanford undergraduate and graduate students in the School of Engineering have the opportunity to work on engineering projects that support international development. Students work in teams with local engineers, clinicians, and staff to address a community-requested problem space and produce an actionable end product. After ten weeks of preparation prior to departure, students are stationed in southwest Uganda for five weeks to practice community-based learning and to work together to solve problems facing KIHEFO and the community it serves.

The SSLP Maternal Health team consisted of three undergraduates and was led by one doctoral student. The three undergraduates are Trisha Shetty, Emily Pang, and Zoe Lee-Chiong. Trisha is a rising third-year undergraduate pursuing a double major in computer science and political science. Emily is a rising third-year undergraduate majoring in mechanical engineering and minoring in feminist, gender, and sexuality studies. Zoe is a rising third-year undergraduate studying biomechanical engineering. Doctoral student Kate Gasparro is a Ph.D candidate in the Civil and Environmental Engineering studying sustainable design and construction. She also holds a Bachelor's in Civil Engineering and is working towards her Master's in International Policy.

Figure 15: SSLP Maternal Health Team
Acknowledgements

The process of creating this document and proceeding with our project was only possible with the help of many great organizations and individuals.

Kigezi Healthcare Foundation (KIHEFO) served as our on-the-ground support for this project. They were extremely helpful with the preparation work and the needs identification phase of this project. KIHEFO provided room and board during our five week project and also provided access to their healthcare facilities and support staff to help with translation. KIHEFO is a local not-for-profit NGO dedicated to community development in the Kabale District of southwest Uganda. It provides a variety of services such as medical care, educational services, economic development, and counseling. Besides being stationed in Kabale, KIHEFO also emphasizes its outreach services in order to provide care to hard-to-reach communities in the greater Kigezi Region. KIHEFO’s mission is to combat poverty and health issues in the Kigezi region by providing education, community services, and health care for communities. Their progressive and innovative perspective was very helpful for guiding and inspiring our project. A special thank you to Dr. Geoffrey Anguyo.

Child Family Health International (CFHI) served as the connection between Stanford and KIHEFO and provided off-the-ground support in a variety of forms. CFHI is a 501(c)3 non-profit that provides students with service-learning experiences around the world. With more than 30+ programs in ten countries, CFHI’s global health education programs focus on community engagement, asset-based development, and commitment to sustainability and long-term local empowerment. They provided preparation materials and insurance for us while we worked in Kabale for the duration of the project. A special thank you to Robin Young who prepared our trip and worked with the team from March 2016 to October 2016.

Stanford University’s Global Engineering Program was instrumental in bringing together the student group and providing the resources for the team. Stanford University's Global Engineering Programs aim to provide students with opportunities to learn first-hand about the role of technology and engineering in an international and culturally diverse environment. A special thank you to Tori Bianchi for her continued support for the SSLP program and guidance throughout our project.

Pulse is a social enterprise that manufactures and distributes motorcycle ambulances in Uganda. Pulse was able to provide us with first hand insights and worked with us to bring a Pulse motorcycle ambulance to Kabale to conduct interviews and get feedback on implementing a motorcycle ambulance system in the Kigezi District. A special thank you to Daryl Funk and Fred Kagara.

Nabassa Barnabas was responsible for planning the majority of the field research and coordinating the interview logistics. He served as our cultural liaison and worked with us to develop a culturally relevant and respectful interview process. Additionally, Barnabas served as the translator for a majority of the interviews.

Hakim and Julius spent several days with us as we interviewed mothers and other stakeholders. They were instrumental in interpreting the interviews and making the interviewees feel comfortable throughout the interview process.

The KIHEFO Maternity Ward Staff worked closely with us during the first stages of our project to ensure that our work was relevant and necessary to their operations. They were a pleasure to work with and spent many hours answering our medically related questions as we worked to better understand their processes.
## Appendix

### Appendix 1: Motorcycle and Bicycle Ambulances

<table>
<thead>
<tr>
<th>Product</th>
<th>Locations</th>
<th>Cost</th>
<th>Included</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sakaramenta Bicycle Ambulancexxiv</td>
<td>Malawi</td>
<td>$350&lt;sup&gt;xxv&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Bikecart&lt;sup&gt;xxvi&lt;/sup&gt;</td>
<td>Namibia</td>
<td>$530</td>
<td></td>
</tr>
<tr>
<td>Zambulance&lt;sup&gt;xxvii&lt;/sup&gt;</td>
<td>Uganda, Zambia, DR Congo, South Sudan, Rwanda, Kenya, Tanzania, Mozambique</td>
<td>$1000 (attachment, bike, shipping, delivery, training, follow-up visits, basic tool kit)</td>
<td></td>
</tr>
<tr>
<td>African Vision Bicycle Ambulance&lt;sup&gt;xxviii&lt;/sup&gt;</td>
<td>Malawi</td>
<td>$530 (bike and training)</td>
<td></td>
</tr>
<tr>
<td>Organization</td>
<td>Country</td>
<td>Cost</td>
<td></td>
</tr>
<tr>
<td>------------------------------------</td>
<td>------------</td>
<td>-----------------------</td>
<td></td>
</tr>
<tr>
<td>FABIO (First African Bicycle</td>
<td>Uganda</td>
<td>$420 (bike, attachment, transport, assembly)</td>
<td></td>
</tr>
<tr>
<td>Information Organisation)xxix</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rickshaw Ambulance xxx</td>
<td>India</td>
<td>$200 (bike construction)</td>
<td></td>
</tr>
<tr>
<td>Zambulance (Vechakul)xxi</td>
<td>Zambia</td>
<td>$310 (attachment construction)</td>
<td></td>
</tr>
<tr>
<td>Ambulance-Trailer (Dennis)</td>
<td>Zambia</td>
<td>$1000</td>
<td></td>
</tr>
<tr>
<td>eRanger Ambulance xv</td>
<td>Malawi, worldwide</td>
<td>$6600 (includes clinical operating abilities)</td>
<td></td>
</tr>
<tr>
<td>Model</td>
<td>Country</td>
<td>Price</td>
<td></td>
</tr>
<tr>
<td>------------------------------</td>
<td>---------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>Kavaki Motorcycle Ambulance</td>
<td>China</td>
<td>$1000</td>
<td></td>
</tr>
<tr>
<td>Pulse</td>
<td>Uganda</td>
<td>$1200</td>
<td></td>
</tr>
</tbody>
</table>
Appendix 2: WTP and Prototype Survey for Service Stakeholders
Stakeholder Survey for Providing a Motorcycle Ambulance

General
1. What is your name?
2. What is your age?
3. Where do you currently live? What is the name of the community?
4. For how long have you lived in this village/community/area?

Mothers

Ability of female to make decisions
6. What is your occupation? How do you make a living?
7. How much money do you make a month?
8. How much money does your household make per month (whole family income)?
9. How much money do you save?
10. What do you save money for?
11. How much does the household save?
12. What does the household (family as a whole) save for?

Availability of transport
13. Have you used boda bodas before?
14. How often (how many times a month) do you use a boda boda?
15. When would you use a boda? (For what reason)
16. What's the range of prices for a boda ride?
17. How many minutes does it take to find a boda in your community?
18. Have you ever needed emergency transport to get to a doctor/PA/traditional healer? Why?
19. How far was/is the doctor/PA/traditional healer (km + min)?
20. What mode would you use for emergency transport?

Community groups
21. Are you a part of a group in the community?
22. What is the group's purpose(s)?
23. What are the membership requirements/barriers to entry for the group?
24. How much per month do you pay/contribute to be a part of the group?
25. Is there a leader? How is the leader determined?

Birthing experience
26. What is your marital status?
27. How many times have you given birth? Are you expecting?
28. Did you face any complications with any of the deliveries? If so, what?
29. How long ago was your last delivery?
30. What is the distance between your home and the closest medical service center, where you might give birth (clinic, hospital, etc.)?
31. Where did you anticipate giving birth? Why?
32. What mode of transport did you use to get there?
33. How far away was it (km + min)?
34. At what point in your delivery did you/will you decide to seek out transport?
35. Who accompanied/will accompany you to the health center?
36. Have you ever been referred from one health center to another for delivery?
37. For what reason were you referred?
38. How did you travel during your referral transit (what mode of transport)?
39. Where was the referral destination?
40. How long was the journey (km + min)?
41. How would you rate the journey (km + min)?

Prototype (have woman sit in prototype and explain the motorcycle ambulance to the woman-flyer/video)
42. Under what conditions would you give birth at the clinic/hospital?
43. Why would you not give birth at the clinic/hospital?
44. What mode of transport would you use to get to the clinic/hospital?

Prototype (have woman sit in prototype and explain the motorcycle ambulance to the woman-flyer/video)
44. How much would you pay for this type of transportation (the motorcycle ambulance)? Price were increased by UGX 10,000?
45. What is the maximum amount you would be willing to pay for this ambulance service?

Community Leaders
51. What is your role in the group and what does the group do?
52. How large is the group (in relation to the community %) (if and a %)
53. What are the membership requirements/obligations?
54. How much do members contribute to the group every month? (If not installments, then what do they pay, if any?)
55. Is there any external funding that the group receives?
56. What are the benefits of being a part of the group?
57. What are the benefits/resources/services allocated to members?
58. Do community members outside of the group get access to group resources/services?
59. How do you/the group make decisions on resource/service allocation?
60. What resources/services have been purchased in the past with group money?
61. What resources/services do you provide for health care?
62. Are there any provisions for taking mothers to medical services centers?
63. Under what circumstances would you provide mothers with transport to medical services centers?
64. How far is the closest medical services center (km + min)?
65. What is the cost for transporting a woman to a medical services center?
66. Would the group be interested in obtaining a motorcycle ambulance for transport?
67. Are there boda drivers in the community who drive members anywhere for hire? If yes, how many?
68. If a motorcycle ambulance were for sale, how much would you/the community group be willing to pay to obtain a motorcycle ambulance?
69. Would you purchase it if the price were to be increased by UGX 100,000 (enter correct value here)?
70. What is the maximum price you would pay for the carriage?
71. How would the community group pay to own the motorcycle ambulance? (one time, pay over time)
72. How would you go about gathering the money to pay for the motorcycle ambulance?
73. How would the motorcycle ambulance be shared among all the community members?
74. Who would be in charge of the motorcycle carriage?
75. Would there be a designated motorcycle driver to take mothers to the medical services center? Would there be a rotating driver designation system?
<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>76. How many customers have you driven in an emergency situation to the clinic/the hospital/Traditional healer?</td>
<td>When you picked her up?</td>
</tr>
<tr>
<td>77. How far away was the pick up location from the health center you dropped the patient at?</td>
<td>When you dropped her at the hospital?</td>
</tr>
<tr>
<td>78. What was the condition of the patient?</td>
<td></td>
</tr>
<tr>
<td>79. How much did you charge the customer for the ride?</td>
<td></td>
</tr>
<tr>
<td>80. How do you decide what to charge your customer for a ride?</td>
<td></td>
</tr>
<tr>
<td>81. How much do you spend in a month on gas?</td>
<td></td>
</tr>
<tr>
<td>82. Have you used your motorcycle to pull anything of this sort before?</td>
<td>Yes</td>
</tr>
<tr>
<td>83. Could you describe what you pulled?</td>
<td></td>
</tr>
<tr>
<td>84. How heavy was it?</td>
<td></td>
</tr>
<tr>
<td>85. Was it difficult to navigate?</td>
<td></td>
</tr>
<tr>
<td>86. Could you describe the driving experience?</td>
<td></td>
</tr>
<tr>
<td>87. How would you feel pulling this on your motorcycle to a medical services center if a mother were in labor?</td>
<td></td>
</tr>
<tr>
<td>88. Do you think that the height of the carriage obstructs your view in any way?</td>
<td></td>
</tr>
<tr>
<td>89. Do you think it would be difficult to navigate while trying to tug this carriage behind you?</td>
<td></td>
</tr>
<tr>
<td>90. Are there any concerns you have about maintenance/repair of your motorcycles if you were to pull this carriage?</td>
<td>How much of an additional monthly/yearly cost would this be?</td>
</tr>
<tr>
<td>91. How much extra fuel usage do you anticipate if you were to pull this carriage x times a day? (preferable answer in litres/km)</td>
<td>How much of an additional monthly cost would this be?</td>
</tr>
<tr>
<td>92. Do you anticipate any problems in/during:</td>
<td></td>
</tr>
<tr>
<td>93. How would you change:</td>
<td></td>
</tr>
</tbody>
</table>
Appendix 3: Financial Model Directions and Screen Shot

### Financial Model: Motorcycle Ambulance Service in Kabale, Uganda

This financial model was developed for Kigezi Health Foundation in Kabale, Uganda to better understand the business model and sustainability of providing a motorcycle ambulance service in the Kigezi District. The financial model can be used by others as well to understand how a motorcycle ambulance service can become a sustainable service under a variety of conditions. This model was developed by Stanford University’s Service Learning Program in September 2016.

#### Payment Scheme

**Insurance**
- Each customer pays a ride fee (this can be either a flat rate or vary based on the distance traveled)

**Pay Per Ride**
- The insurance company pays the service providers a set amount every month or a set amount per every ride given

#### Assumptions

<table>
<thead>
<tr>
<th>Type of Service</th>
<th>Frequency</th>
<th>Units</th>
<th>Notes</th>
<th>Range</th>
<th>Default</th>
<th>Reasoning</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year Starts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2015</td>
<td>2016 Year model</td>
</tr>
<tr>
<td>Month Started</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1-12</td>
<td>10 Month mos</td>
</tr>
<tr>
<td>Months per Year</td>
<td>Months</td>
<td></td>
<td></td>
<td></td>
<td>1-12</td>
<td>12 - Hope that $</td>
</tr>
<tr>
<td>Inflation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&gt;&gt;0</td>
<td>12 Average Ug</td>
</tr>
</tbody>
</table>

#### Transportation Details

<table>
<thead>
<tr>
<th>Distance to Medical Services Center (average)</th>
<th>Per Ride</th>
<th>Km</th>
<th>Average distance the service will be provided for; if the service is offered in one community, then the distance will generally remain the same; but, if the service is offered for a group of communities, the average distance the service operators will have to be calculated</th>
<th>&gt;&gt;0</th>
<th>5 Most comm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning Rides</td>
<td>Monthly</td>
<td>Customers</td>
<td>Number of rides given in the first month of operations; the rides can be determined by the number of expectant mothers near term and the very ill/injured that can afford the service</td>
<td>&gt;&gt;0</td>
<td>10 Number of</td>
</tr>
<tr>
<td>Maximum Rides</td>
<td>Monthly</td>
<td>Customers</td>
<td>Number of maximum rides that can be given in any month; this is based on the drivers ability to give rides in a month and can be determined by the length of each ride (at return journey) and the hours the service operates during the day</td>
<td>&gt;&gt;0</td>
<td>60 Assume can</td>
</tr>
<tr>
<td>Ratio of Customers with Insurance</td>
<td>Monthly</td>
<td></td>
<td>Rate at which the rides per month increases until reaching the maximum rides number; if the service is very popular and expands quickly, then the rate will be high; but, if it takes a while for individuals to learn about the service and save enough money for the service, then the rate will be lower</td>
<td>&gt;&gt;0</td>
<td>10 Assume slow</td>
</tr>
</tbody>
</table>

#### Revenue

**Pay Per Ride**
- Ride Price: Per Ride UGX/ride
  - Price that the driver will charge a customer for one-way ride to the medical services center; this is the entire price of the ride; this can be determined through willingness-to-pay study
  - >>0 10000 Willingness
- Ride Price per Km: Per Kilometer UGX/km
  - Price that the driver will charge a customer per kilometer of the ride
  - >>0 1000 Willingness

**Total Ride Price**
- Per Ride UGX/ride
  - and the ride price per kilometer multiplied by the average distance of a ride to the medical services center calculated

**Insurance**
- Percent of the Insurance that is dedicated to the ambulance service in a month (if the amount is not based on a percentage, then the cell can be overridden and you can type in the correct amount; to change the cell back to its original formula enter the following formula in the cell: =C3*33+33)

#### Type of Insurance

<table>
<thead>
<tr>
<th>Type of Insurance</th>
<th>Notes</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Individuals</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Household Insurance Payment</td>
<td>Monthly</td>
<td>UGX</td>
</tr>
<tr>
<td>Individual Insurance Payment</td>
<td>Monthly</td>
<td>UGX</td>
</tr>
<tr>
<td>Total Insurance Collected</td>
<td>Monthly</td>
<td>UGX</td>
</tr>
<tr>
<td>Percent of Insurance for Motorcycle Ambulance Subsidy</td>
<td>Monthly</td>
<td>UGX</td>
</tr>
<tr>
<td>Total Insurance for Motorcycle Ambulance Subsidy</td>
<td>Monthly</td>
<td>UGX</td>
</tr>
</tbody>
</table>

#### System Subsidy

<table>
<thead>
<tr>
<th>Type of Subsidy</th>
<th>Notes</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Subsidy</td>
<td>One Time</td>
<td>UGX</td>
</tr>
<tr>
<td>System Subsidy Frequency</td>
<td>Every</td>
<td>Years</td>
</tr>
<tr>
<td>Customer Subsidy</td>
<td>Per Ride</td>
<td>UGX/ride</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Costs

**Motorcycle**
- Market price of the motorcycle; this is usually provided by the motorcycle distributor
  - >>0 3700000 Current p/c
- Price for upgrading parts of the motorcycle or purchasing accessories for the motorcycle
  - >>0 750000 Price of can
- Life Span of the motorcycle; the purchase of the motorcycle will occur at the end of the life span
  - >>0 7 Assumption
- Life Span
  - Amount of kilometers that the motorcycle can go with one liter with the ambulance attachment, studies have shown that the fuel efficiency when the motorcycle has to handle additional loads |
  - >>0 | 20 Literature a |
- Fuel Efficiency Km/liter
  - Market price of a liter of gasoline
  - >>0 | 3320 Current p/c |
- Fuel Cost UGX/liter
  - Price for servicing the ambulance on a monthly basis; this includes oil changes, spare part purchasing, cleaning, etc.; in our interviews the average maintenance cost was 50000 UGX/month |
  - >>0 | 50000 Interviews |

**Ambulance Attachment**
- Market price of the motorcycle attached; this is provided by the motorcycle ambulance manufacturer and distributor
  - >>0 3300000 Market p/c
- Life Span
  - Life span of the motorcycle attachment; the purchase of the ambulance attachment will occur at the end of the life span |
  - >>0 | 7 Assumption |

**Ambulance Attachment Maintenance**
- Price for servicing the ambulance attachment in a year; this includes spare part purchasing, labor, welding, etc.
  - >>0 | 100000 Assumption |

**Driver**
- Monthly salary/payment to compensate the driver for his/her time, talent, and service
  - >>0 | 290000 Interviews |

**Call Center**
- Monthly payment to compensate the call center personnel for his/her time, talent, and service, if the driver is also the call center, then this number should remain 0 |
  - >>0 | 0 Currently in |