

AC 2010-1732: APPLYING SYSTEMS THINKING FOR REALIZING THE MISSION OF TECHNOLOGY-BASED SOCIAL VENTURES IN AFRICA

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Applying Systems Thinking for Realizing the Mission of Technology-based Social Ventures in Africa

Abstract

There are many university initiatives that focus on technology-based solutions to address the needs of marginalized communities. The technology-based solutions are intended to be economically and socially sustainable. These endeavors are usually well-meaning, creatively designed, and enthusiastically deployed, but do not achieve the sustainable impact envisioned at the outset of the projects. To address these shortcomings, at The Pennsylvania State University we are applying three key tenets of systems thinking to our humanitarian engineering and social entrepreneurial ventures: 1) employing regulation via feedback to ensure that the system is actually working; 2) defining systems by their interactions and their parts; and 3) understanding that systems exhibit multi-finality. The concept of multi-finality refers to (designing) a system where the individual actors (inputs), the subsystems, and their interactions, all meet their own goals while the system as a whole also meets its goals. In this paper, we lay the framework for the application of specific systems thinking concepts to increase the probability of success of global development ventures. We provide simple yet compelling examples from two different ventures to illustrate the power of systems thinking to train innovative problem-solvers and increase the probability of success of technology-based social entrepreneurial ventures in Africa.

Introduction: Need for Systems Thinking

There are many university initiatives that focus on technology-based solutions to address the needs of marginalized communities—the poor, the underserved, i.e., those at the “Base of the Pyramid”. The technology-based solutions are intended to be economically and socially sustainable. These endeavors are usually well-meaning, creatively designed, and enthusiastically deployed, but do not achieve the sustainable impact envisioned at the outset of the projects. On the macro scale, the history of development efforts to assist marginalized communities in a sustainable fashion has been fraught with peril. In 2004, the African Development Bank judged 78% of its funds disbursed were for projects that were not sustainable.¹ The Independent Evaluation Group (IEG), the World Bank’s private sector arm, examined the performance of 627 projects under implementation between 1996 and 2006 and discovered that over 40% of all projects were unsuccessful at generating positive development results. It is even more distressing to learn that, when assessment of such projects is broadened to encompass a timeframe beyond the immediate completion of projects, the number of favorable assessments falls considerably.

Peter Senge² explains that “Systems thinking is a discipline for seeing wholes. It is a framework for seeing interrelationships rather than things, for seeing patterns of change rather than static ‘snapshots’...Today systems thinking is needed more than ever because we are becoming overwhelmed by complexity. Perhaps for the first time in history, humankind has the capacity to create far more information than anyone can absorb, to foster far greater interdependency than anyone can manage, and to accelerate change far faster than anyone’s ability to keep pace.”

Systems thinking offers insights on how external agencies can facilitate change and internal capacity development processes. It can help determine the optimal allocation of external resources and improve the impact of university and development agency initiatives. Systems thinking encourages a holistic view of development challenges. Areas targeted for intervention are looked at as part of a complex web of interconnected and interacting systems and subsystems. This forces attention on the larger picture and wider processes of change rather than concentrating on discrete outputs at the project level.³ At the same time, systems thinking can help us avoid unintended consequences by making us aware of how they may be created by previously unrecognized feedback cycles or delays.

Entities as diverse as educational institutions, non-profits, private development organizations and charities, governments, and United Nations agencies are engaged in the global development arena. The “NGO mentality” is prevalent, and synergizing to affect larger social change in impoverished communities is not the norm.⁴ Often times, there is no equity between the agencies and the communities that are going to benefit from the interventions. Projects where people do not have a sense of ownership in the solutions are less likely to succeed. Finding the optimal distribution of time, money, and sweat equity to be shared by the communities and partnering universities and organizations is critical to achieving sustainability.⁵ The search for equilibrium in this extremely complex context necessitates a systems thinking approach.

Introduction: Our Approach to the Praxis of Systems Thinking

There is no uniform body of thinking related to systems thinking. We have developed our understanding of systems thinking after studying the works of pioneers like Peter Senge, Russell Ackoff, and Jamshid Gharajedaghi. Our team’s experiences leading technology-based social ventures in East Africa over the last six years and myriad of philosophical discussions have helped us internalize the philosophies of systems thinking. We have developed simple methodologies to apply various tenets of systems thinking to make our ventures more realizable and sustainable. Sustainable solutions have four hallmarks: technologically appropriate, environmentally benign, socially acceptable, and economically sustainable.⁵ We seek a balance between creating sustainable value for developing communities and educating the next generation of problem solvers who are capable of seeing the big picture, understanding how the larger systems of the world work (and do not work) together, and developing innovative solutions that meet the immediate needs of the users while empowering them over the longer term.

We are applying three key tenets of systems thinking to our ventures: 1) employing regulation, i.e., defining a closed-loop system with feedback to ensure that the system is actually working; 2) defining systems by their interactions and their parts; and 3) understanding that systems exhibit multi-finality. We are designing a closed-loop system where all the stakeholders truly understand their roles and have direct incentives to participate in the process and there are feedback mechanisms for accountability. The process and the user experience should be clear to the stakeholders and there should be specific checks and balances to ensure that the process is actually followed. Rewards for participation are based on the quality of the transactions. The concept of multi-finality (as interpreted by us) refers to (designing) a system where the

individual actors (inputs), the subsystems, and their interactions all meet their own goals while the system as a whole also meets its goals.

In this paper, we lay the framework for the application of these systems thinking concepts to increase the probability of success of service-learning and global development ventures. We have provided examples of the application of the three tenets to the development of two complex technology-based social ventures in Kenya. The work described in this paper was conducted within the confines of a senior-level engineering design class that brought together twelve students from eleven majors across six colleges at The Pennsylvania State University.

The concept of systems thinking was presented to the students in a related seminar class on “Design for Developing Communities” within the context of the UN Millennium Development Goals (MDGs). The key point was that the MDGs are distinct yet intricately interconnected with solutions targeting one MDG typically affecting other MDGs, too. Examples related to the three tenets of systems thinking considered in this paper were discussed in class, after which the teams applied the concepts to their ventures with guidance from the course instructor. The most useful resource on systems thinking (besides the instructor) was the brief Wikipedia entry on systems thinking.⁶ The next section of this paper discusses the two ventures in sufficient detail followed by the application of the systems thinking concepts for the design of these ventures.

Humanitarian Engineering and Social Entrepreneurship at Penn State

The College of Engineering at Penn State has numerous ongoing humanitarian engineering and social entrepreneurship (HESE) initiatives.⁷ The basic philosophy behind the initiatives is the convergence of concepts, disciplines, cultures, and countries towards a freer, fairer, friendlier, and more sustainable planet. HESE challenges students and faculty from across the campus to break down the barriers between their disciplines and truly collaborate to develop technology-based solutions to address the most compelling problems facing humanity today. The objective is to develop transformative social innovations and scalable business models to transform these technology solutions into sustainable and scalable ventures that enable and accelerate positive social change throughout the world.

HESE seeks the convergence of the tripartite university missions of teaching, research, and service (or outreach) to educate globally-engaged social problem solvers and to create sustainable value for developing communities, while generating and disseminating knowledge and lessons learned. The real-world context and focus on indigenous communities around the world fosters “inreach”: the bringing back of knowledge, perspectives, problems, and solutions to inform, guide, and enrich the program. Subject matter experts from industry and the professional world, as well as local knowledge experts advise and mentor the students engaged in the various ventures and research initiatives. HESE has developed long-term relationships and work with industry, government, non-profit, faith-based, and UN partners spanning colleges, universities, countries, and continents. More than 300 students and over twenty faculty members representing almost all colleges at Penn State participated in various HESE initiatives in 2009.

A twelve-credit certificate program in Engineering and Community Engagement is offered to undergraduate students from all disciplines. The most important piece of the certificate program

is participation in a technology-based social venture that is integrated into academics by way of the “eplum” model of student engagement.⁸ Systems thinking is emphasized in all the ventures and initiatives associated with HESE and applied where possible. The work described in this paper was conducted on two ongoing ventures in Kenya: a telemedicine system called Mashavu and a cell phone–based social networking system called WishVast. These ventures have been explained in detail in the next section.

Mashavu: Networked Health Solutions for the Developing World

There is one doctor for every 50,000 people in East Africa compared to one doctor for every 390 people in the United States.⁹ In East Africa, it costs a significant amount of time and money to consult a doctor—and the critical decision to even consult a doctor is often made too late leading to more severe health problems. Mashavu is a telemedicine system that enables medical professionals around the world to connect with patients in the developing world using modern technology and communications infrastructure.¹⁰ Trained operators at Mashavu stations in developing communities collect essential medical information including weight, body temperature, lung capacity, blood pressure, photographs, stethoscope rhythms, and basic hygiene and nutrition information for each patient. We are designing ultra-inexpensive biomedical devices based on virtual instrumentation. Web servers aggregate this information from various Mashavu stations over a cell phone link and provide it on a web-based portal. Medical professionals can view the patient’s information and respond to the patient and the nearest doctor(s) with their recommendations. Validation efforts prove that numerous entities are willing to purchase and operate Mashavu stations. They can charge customers a small fee, thereby making Mashavu economically sustainable and creating an additional revenue stream.¹¹ Additional income streams are created through the maintenance of the Mashavu system as well as the manufacturing and maintenance of the biomedical devices.

The over arching goals of Mashavu are:

1. Improved access to pre-primary healthcare,
2. Active community health education,
3. Socio-economic development through micro-enterprise, and
4. Transforming students (everywhere) into entrepreneurial global citizens.

The Mashavu team aims to:

1. Design, prototype, and test inexpensive computer-based biomedical devices (Mashavu station) and the networked system (Mashavu network);
2. Perform preliminary on-the-ground testing of the Mashavu stations, Mashavu network, and the business plan; and
3. Implement the system in a top-down manner and bottom-up manner and craft the final scale-up strategy based on lessons learned.

Mashavu Teams: The development of Mashavu is tightly integrated into academics through the eplum model of student engagement with a number of courses working on various aspects of the venture.⁸ A one-credit seminar course grounds students enrolled in the various courses in the basics of humanitarian engineering, user-centered design for extreme affordability, social entrepreneurship, systems thinking, travel and fieldwork, and related issues. Project management

meetings are held during the seminar class to ensure that students work together towards a common goal. As shown in Figure 1, the Mashavu core team forms the nucleus of the venture and is housed in a two-credit senior-level engineering design class with a number of other courses working on various aspects of the venture.

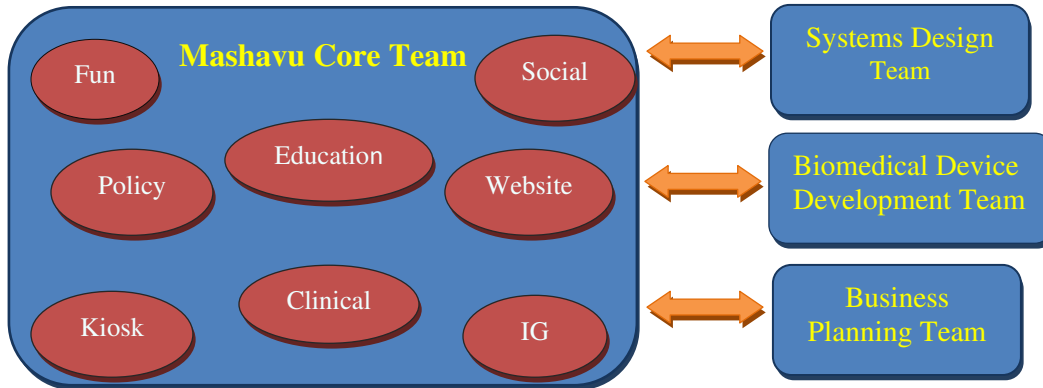


Figure 1: Teams working on the Mashavu venture

Mashavu Core Team: During the Spring 2009 semester, when the work discussed in this paper was conducted, 12 students from 11 majors across six colleges participated as members of the core team. These students were championing different aspects of the venture including kiosk design, website design, education, fun/entertainment, social harmony, instant gratification, and clinical encounter, as well as the legal team primarily who were tasked with the development of the code of ethics.

- **Kiosk Design:** Mashavu is a computer-based system and the kiosk design team was responsible for developing the software program that communicates with all the biomedical devices.
- **Website Design:** Design of the website that aggregates data from all the Mashavu kiosks and offers it on a secure site to the closest doctor as well as (consulting) international doctors.
- **Education:** Developed material that would be used to educate the users of Mashavu. These materials include information for the patient and operator as to how Mashavu works, as well as information for the patient on the measurements taken by the Mashavu system.
- **Fun/Entertainment:** Focused on making the system engaging and entertaining for each of the stakeholders.
- **Instant Gratification:** Determining and embedding incentives along each step in the Mashavu process for each of the stakeholders.
- **Social Harmony:** Examined how designs and programs within Mashavu would fit into East African society. How would things work with the social norms and power systems?
- **Clinical Encounter:** Ensure that a patient's visit would resemble a face-to-face visit with the doctor. Designed medical records that would reflect the information a doctor needs to do a proper evaluation.

- **Legal:** Developing the Mashavu code of ethics to be followed and compliance mechanisms for the various stakeholders. Evaluating legal and liability issues related to technology-transfer and ensuring privacy for the patients.

Biomedical Device Design Teams: A junior-level bioengineering class (BIOE 401: Introduction to Biomedical Research and Design) with 48 students worked on the design of the inexpensive biomedical devices based on virtual instrumentation. The biomedical devices included a stethoscope, adult weighing scale, thermometer, infant weighing scale, pulse monitor, spirometer, and blood pressure measuring device. Student teams with six members used finite element analysis and rigorous design methodologies to design the devices. They constructed and tested the prototypes and the students who traveled to Kenya in the summer conducted field testing.

Business Planning Team: The preliminary business plan for Mashavu was developed by a five-member team in the BA 301H: Finance honors class as a commissioned assignment. One of the team members attended the seminar class and the entire team worked closely with the core team to develop a good business plan.

Systems Design Team: A graduate-level engineering design class on Systems Design (EDSGN 597C) designed the Mashavu system from a systems perspective and developed comprehensive documentation to enable the organic growth of Mashavu and facilitate the design of the system over multiple iterations.

Mashavu Validation: By working with the communities and the local government in Kenya, we have found that Mashavu is a viable solution for connecting patients in the rural communities of East Africa to local doctors. During the summer of 2008, students conducted fieldwork focused on validation in Tanzania, and found that the top five reasons for seeking medical care were malaria, acute respiratory infections (ARIs), pneumonia, skin infections, and diarrhoeal diseases, and 45 % reported that they had chronic health problems like diabetes, hypertension, and lung problems. This data shows that Mashavu could be used to detect the most common illnesses, including skin and eye infections and ARIs, and common chronic health problems such as hypertension and lung problems could be monitored regularly using Mashavu.¹¹

Usability testing was conducted in Tanzania where several students met with orphanage caregivers, who were middle-aged or older women and had never touched a computer or biomedical devices. The caregivers quickly learned how to use the computer program and were teaching one another within 15 minutes. These caregivers were able to interact with the computer and navigate the graphical user interface for the Mashavu kiosk. Mashavu's interface is easy to learn and requires basic navigation of the computer program for the Mashavu operator.

Doctors in Tanzania expressed interest in owning a Mashavu kiosk to assist with check-in and triage of patients.¹¹ In Kenya doctors suggested that Mashavu would be particularly useful for follow-up appointments. The kiosk would allow patients to stay closer to home but still communicate with the doctors. While there are few doctors in East Africa, they do still have time to spare to see patients, but the problem is that patients are not coming to the clinics when they

have minor issues. To doctors, Mashavu would help these patients make the decision to see a doctor rather than waiting until the health issue becomes more difficult to treat.

WishVast: Building Trust and Social Capital using Cell Phones

In addition to using the power of cell phones for healthcare purposes in East Africa, they can also be leveraged for myriad other purposes. WishVast harnesses the power of cell phones in developing countries to build trust and optimize resource utilization and supply chains to facilitate people-to-people trade with the ultimate goal of alleviating poverty.¹²

Cell phone-based social networking applications are gradually making inroads into the American and European markets with over 30 startups competing in these markets.¹³ According to the latest data from the U.S. Central Intelligence Agency, there are approximately 4.1 billion cell phone users worldwide, and it is estimated that 97% of people in Tanzania have access to cell phones.¹⁴ The pervasiveness of cell phones is very similar in Kenya. Many of these people do not have internet access and can be reached only by phone. As the availability of mobile phones in developing regions continues to increase rapidly, so does the ability to reach people in geographically dispersed places. Connecting people in rural communities with each other and to people in urban areas is essential to achieving a fully integrated and thriving society. Facilitating the creation of trusting relationships is an essential step after connecting people. A study of the social networks of women agro-entrepreneurs in northern Tanzania revealed that the single most important component when conducting business is trust. Despite limited access to financial resources for individuals in developing regions, trust is more important than price, logistics, and other factors when conducting business.¹⁵

As shown in Figure 2, the WishVast technology is built on a cell phone tethered to a laptop. The laptop runs the “WishVast Network Management System” software, which was developed by our team as a cross-platform Java application. This application allows the cell phone to receive messages from WishVast’s users via SMS text messaging, then routes the messages appropriately by interfacing with a database on the computer. To use the system, WishVast users need only their cell phones without any modifications or additional software.



Figure 2: The WishVast hardware: one laptop, one cell phone, one USB tether.

WishVast users can join groups of local relevance and send SMS text messages to the entire group to advertise themselves, their products or services, or get access to resources.¹⁶ WishVast users can realize the value of their current social networks, forge new relationships, and expand their social and business networks. Upon the completion of a transaction over the WishVast network, users can exchange points to rate the quality of their interaction. This is similar to eBay’s current model of buyer/seller feedback. Over time, these points add up, allowing people to build a digital reputation. WishVast can be used by many different users for many different things. For example, employers can use the system to find employees and produce farmers can find potential customers.¹²

During the summer of 2009, students validated the technology and a number of applicable scenarios in which WishVast had a strong value proposition. During the summer of 2010, students will continue to validate the technology and scenarios while actually piloting the system with users in Kenya. The system eventually can be easily integrated into the existing Safaricom and Zain cell phone networks where it can become part of their existing infrastructure for maintenance and upgrade purposes.

Mashavu: Defining Systems by Their Interactions and Their Parts

Mashavu is a complex venture in itself because it has diverse users and stakeholders, hardware and software subsystems, and numerous potential application scenarios. Mashavu operates alongside and within a number of larger systems that form the context for the venture, shown in Figure 3. It was critical for us to understand how Mashavu’s subsystems interacted with each other. We had to examine how these interacting systems operated in East Africa and how Mashavu would fit into each of these systems. Exploring the context of these systems allowed us to better understand the stakeholders and how the systems would impact the stakeholders’ interaction and the design of Mashavu.

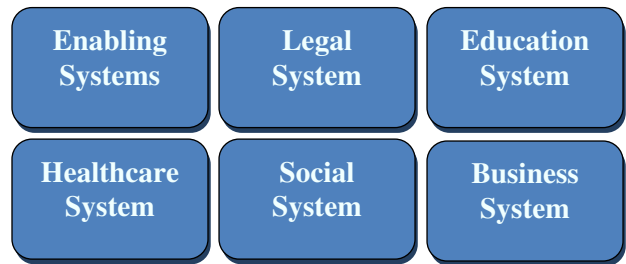


Figure 3: Interacting Systems for the Mashavu venture

The primary interacting systems for Mashavu are:

Enabling Systems: Mashavu depends upon a number of enabling systems, including the power (electricity) system, cell phone networks, and the internet to perform its tasks.

Legal Systems: Local doctors and Mashavu operators act in compliance with the healthcare policies and privacy norms in Kenya.

Education System: One of Mashavu's goals is to provide active community health education. The educational materials depend on the current education levels and attitudes amongst the people in the partnering communities.

Healthcare System: Mashavu provides the community members with their first line of defense on health issues. It works alongside the existing healthcare system and requires the assistance of local doctors and doctors abroad.

Social System: Social norms and power relations will determine the interaction of the Mashavu systems with the various stakeholders. For example, Mashavu will require the interaction between different genders in a medical setting.

Business System: Mashavu is an entrepreneurial venture that is eventually going to be set up as a micro-enterprise. Micro-franchises are gaining popularity in Kenya: M-pesa and EkoToilet are two examples of successful ventures which are solving social problems and supporting livelihoods through microenterprise at the same time. The general population is familiar with the concept of micropayments, with cell phone credit being the most widespread micropayment made by millions of Kenyans every day.

Throughout the semester the core team focused on designing the Mashavu user experience that actively engages the various users throughout the process. Since most of the Mashavu users will be unfamiliar with computers and will have lower education levels, it is essential that the system be easy to use and learn. Children are a large share of the users, and it was essential that the system be fun to use rather than a chore. In order to achieve this user-centered design and lay out the entire concept of operations, we developed a master chain to map the entire Mashavu process and explore the various interactions between the Mashavu users, Mashavu subsystems, and the interacting systems in the operating environment.

The master chain is the end-to-end business process for Mashavu that is used to explore how the stakeholders will interact with the system and gain value at each step. Overall, the exercise helped the team determine how Mashavu should operate and the systems that Mashavu operates within. It led to many systemic improvements and showed the sub-teams how they must interact to achieve their individual goals while helping the stakeholders achieve their goals. More importantly, this process helped identify aspects of Mashavu that may not work within the operating environment primarily due to incorrect assumptions about and conflicts of interests with the interacting systems and concerned stakeholders.

The team developed two master chains by looking at the concept of operations from the client's side and the doctor's side. The client value chain in Figure 4 begins from the point when the patient comes to the Mashavu kiosk and ends when the doctor is notified of a patient's concern. This chain starts with a decision as to why the patient is visiting the Mashavu station, which includes an emergency, an illness, or a checkup. If there is an emergency, the operator will skip the Mashavu exam and use the cell phone to call the doctor immediately. Otherwise, the operator will proceed with the examination by logging onto Mashavu, entering any patient data, and taking the patient's vitals. These vitals and any patient information will be sent through the GPRS modem (or a tethered cell phone) to a doctor and the doctor will receive an instant notification.

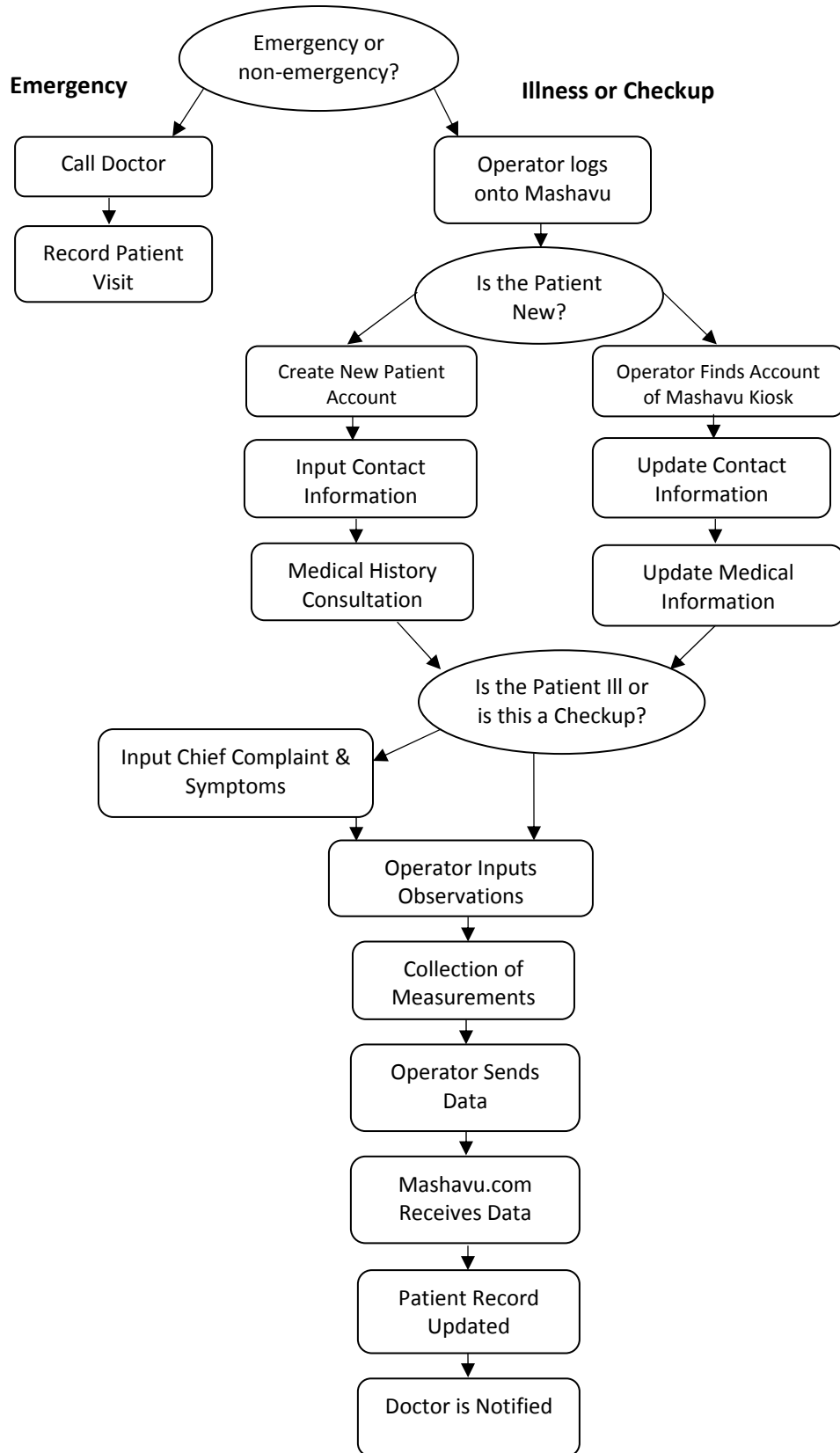


Figure 4: Master chain from the patient's side

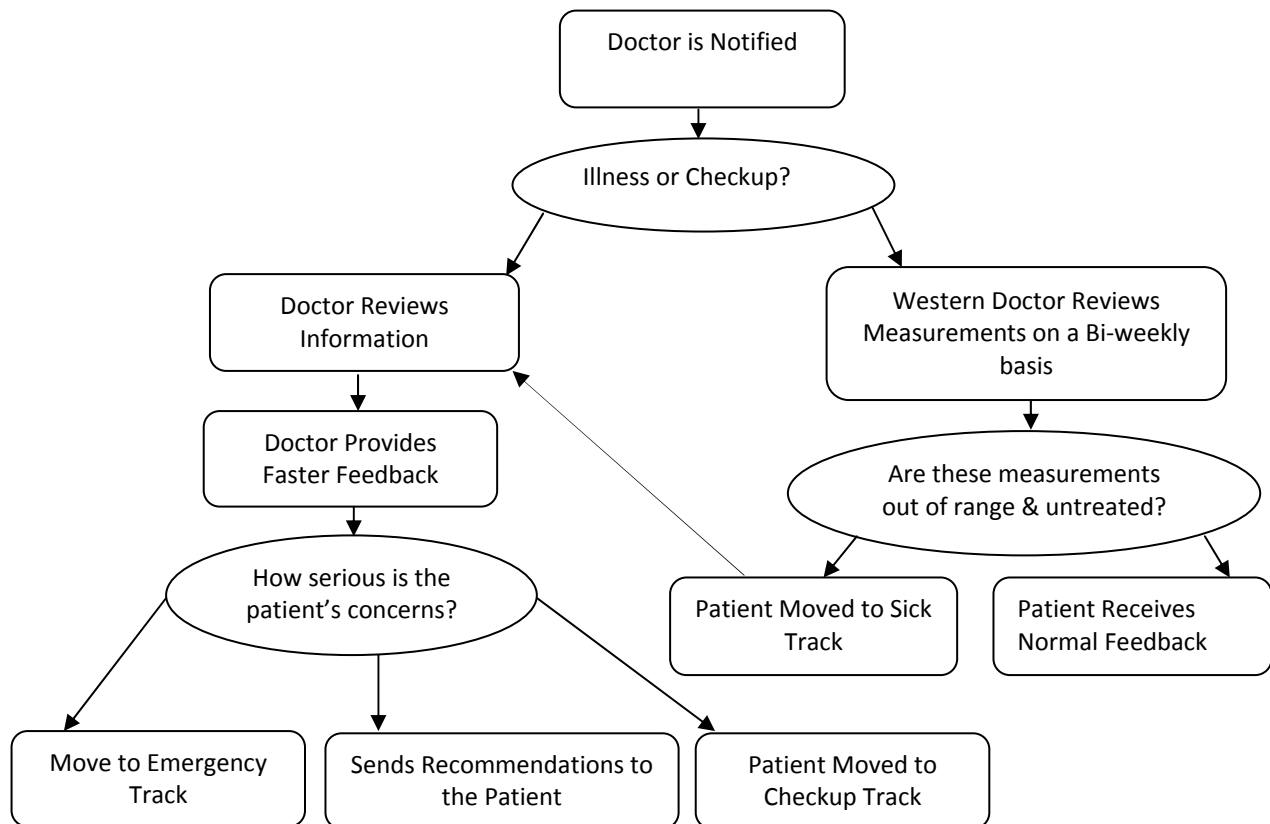


Figure 5: Master chain from the doctor's side

The master chain from the doctor's side in Figure 5 starts when the doctor is notified of a new case to when the patient either follows the doctor's advice or chooses some alternative option. The doctor must review the cases and return advice to more urgent cases first, and afterwards the doctor spends time reviewing checkups. Ultimately, the doctor must respond to all cases in a timely manner.

After creating the master chain, each sub-team evaluated what happens at each step from their own perspective. Each team used the following questions to guide their exploration of how each step (every single box in the master chain) affects their design and its interactions with the other sub-teams and the operating environment. Students were encouraged to think of each interaction as a "game" played by the various stakeholders. The guiding questions included:

- Who are the players?
- When do they play the game?
- What is the game?
- What motivates them to play the game?
- How do they play the game?
- Where do they play the game?
- What are issues they might encounter?
- What factors are there to consider?
- How do factors like age, gender, social status, and/or physical capabilities impact this step?

After each sub-team answered each of these questions for each of the steps, a member of the team aggregated the data into one document. This comprehensive document outlined each step in the value chains and included each of the sub-teams' analysis below the respective step. The document was then sent to each of the group members to read through to gain a better understanding of their own subsystems and how the other subsystems and their goal or concerns interact along each step in the process. These observations were discussed in the class to identify synergies and potential concerns and then refine the Mashavu concept of operations.

E-Adoption: This was one of the early models considered for Mashavu as a way to motivate doctors to join the Mashavu network and to ensure that children were being cared for in orphanages in East Africa. We received sufficient validation from the various stakeholders that this model was very valuable and would help improve the quality of life for orphans. In this model, a foreign doctor adopts a child and reviews the child's measurements periodically to check the child's development. The caregiver at the orphanage would then be responsible for fulfilling this doctor's advice. After analyzing the master chain system interaction data, we realized that the caregiver is given limited resources by the director of the orphanages and may be unable to take the child to the doctor or provide the necessary treatment. With a complete understanding of the social/power system at the orphanage and the interactions of the Mashavu system with the various stakeholders including the child, remote doctor, local caregiver, and the orphanage's director, we found that e-adoption would not work within the context. The exercise allowed us to explore these programs and discover their flaws by strictly looking at the interacting systems and understanding the players.

Priority Flag: After completing the decision portion of the client value chain, the team realized the variety in the severity of cases a Mashavu operator will see. The team found that there was no method for doctors to determine which cases should be reviewed first, and the ability to communicate urgency was missing from the Mashavu system. The concept of a priority flag was adopted to mark cases that required more timely responses than those who had come to the station simply for a checkup. If a patient with an urgent case visits the kiosk and does not receive a more speedy response from Mashavu than the patient would receive at the hospital, Mashavu does not meet its goal of improving access to healthcare nor does it create value in the system for the patient. Less timely responses threaten the Mashavu micro-enterprise because the patient loses value in the service that Mashavu provides. The team realized that the Mashavu system was not operating effectively to provide its patients with the best access to healthcare and in doing so the Mashavu goals of improving access to healthcare and socio-economic development suffered. Through examining how the stakeholders interact and the overlapping systems of Mashavu operate, the team was able to improve parts of the Mashavu system that were not operating effectively.

Adapting the System to Encompass All Users: We discovered that we could improve access to Mashavu services for the physically disabled and elderly by adapting the system in two different ways. Traveling for the physically disabled and elderly is very difficult due to road conditions and the lack of a developed transportation system. While evaluating "where the game will be played?" and "how it would differ for the physically challenged and elderly," we realized that for some patients, the Mashavu kiosk will need to visit them rather than the other way around. Since

the Mashavu station could run from the laptop battery for a period of time, the operator could visit the homes of the physically disabled or elderly.

This issue stemmed from the patients' interaction with the transportation system that does not have the proper equipment for accommodating those confined to a wheelchair. When we tested Mashavu in Kenya, we had multiple requests for Mashavu to come visit them due to the difficulty and costs involved with traveling even short distances. There was actually no transportation system in the community in which we held a Mashavu clinic and people were required to walk if they wanted to access the service.

The second problem we found was the original design for the weighing scale required the person to stand on the scale. After considering that people may be confined to a wheel-chair, we revised this design, which led to an added component that would allow the physically challenged person to get their weight. Both of these issues where Mashavu was not operating effectively were discovered through learning more about our users and the systems with which they interacted. Through exploring the end-to-end business process, we were able to make adjustments to the designs to better accommodate all patients and the other stakeholders.

Negotiation between the Teams: With many aspects of Mashavu, we found that the sub-teams must negotiate to promote the most effective solution for different parts of the system. The legal sub-team was concerned that people might not want a lot of medical information transferred onto the internet. However, the clinical sub-team indicated that doctors would need this information to feel comfortable giving the patient any advice. This issue led to the solution of providing adequate security in the system, which the kiosk design team and the website team implemented. We found through this process that each sub-team needed to zoom out from their individual goals in order to see how we could best advance the system. We learned that there would be many issues that overlap between sub-teams and that would need to be solved together. In addition, we found that many times goals would overlap. For example, we found that many steps needed the participation of both the entertainment and education team in the examination process. It was then that these sub-teams realized they could integrate the goals by making an educational video or an interactive module for learning. After this exercise, the team had a fuller understanding of how Mashavu worked and how their sub-teams overlapped and needed to negotiate to make Mashavu more realizable and sustainable. After aggregating the teams' different perspectives into the master list, we were able to better evaluate the relationships, interactions, and overlaps within the subsystems and with the external interacting systems.

WishVast: Defining Systems by Their Interactions and Their Parts

WishVast is being designed to facilitate quality interactions and reward positive behavior with expanded opportunities. The goal is to accelerate the development of trusting relationships between individuals who would not have met otherwise or built relationships. The trusting relationships form the social capital of these individuals, which can be leveraged to get access to other forms of capital with the ultimate goal of alleviating poverty.

Trust and social capital are complex constructs and, though intrinsically intangible and difficult to quantify, their implications are very real and apparent. We used the systems thinking tenet that

systems can be defined by their interactions and their parts to understand how we can enable WishVast users to build trust and social capital, which lead to tangible benefits within the framework of the various interacting systems that form the context for the operation of WishVast. An understanding of these interactions is critical to helping WishVast meet its social goal of building trust and social capital and its economic goal of becoming economically self-sustainable.

Some of the systems that form the operating context for WishVast in East Africa, each with a different significance, are:

- The agriculture system is important in an agrarian economy with a very significant number of people connected to farming. In the agricultural sector, several studies have shown that farmers prefer receiving information from people they know and trust and who are familiar with the local farming conditions.^{17, 18} Small farmers generally learn about best practices and exchange knowledge only with peers in their immediate social networks. With higher literacy levels and better access, they might be able to build and consult with extended social networks and increase their profits.¹⁹
- The finance system is important in an impoverished society in which access to financial capital is difficult and a major obstacle to development. Individuals in this society are dependent upon microfinance and informal lending to make a living. The phenomenal success of microfinance has established the importance of social networks and peer pressure in keeping borrowers honest and hard working.
- The trust and social capital Systems are important in a society that values trust above other factors like profit when doing business. A study of women agro-entrepreneurs in Tanzania showed that they truly value long-term relationships and base their business relationships on trust and respect. Loyalty and relationships are more important than price.¹⁵ This high value and dependence on trust was validated during the spring 2009 discussions in Kenya.¹⁶

While the aforementioned systems can operate in silos, their true benefit is realized by their interactions. In East Africa, “who you know” network knowledge systems appear to be prevalent and may extend beyond an individual’s immediate social network to a larger collective network that may provide a useful advantage in social, political, or economic situations.²⁰

To illustrate how these systems work together, an example is a macadamia nut broker who works during nut season but is looking for work in the off-season. In East Africa, farming macadamia nuts is a big business, and is a big part of the Farming Economics System. Kenya alone is currently responsible for 10% of the world’s total macadamia nut production, and their exporting of macadamia nuts has increased over the past few years. Kenya exported 6,030 tons of macadamia nuts in 2003, with exports rising to 11,100 tons in 2007.²¹ Each season, nuts are harvested by the estimated 100,000 macadamia nut farmers in Kenya. These individual farmers pick, dry, shell, and clean the nuts that grow on their farms, but once this process is complete, they have few options for what to do with these nuts. Most do not have the time or ability to take them into town, where demand for them would be limited anyway, so the only option they have is selling the nuts to brokers. The brokers compete with each other to buy from as many farmers as possible and maximize their profits.¹⁶

In order to set themselves apart, brokers desire to build up a positive reputation, through trust and social capital. If a broker is only well known by a small group of people, anonymous farmers will not have any way to gauge if he or she is fair. With WishVast, individuals have the ability to rate transactions after interacting. That type of information about an individual builds up over time and is transparent. Through positive experiences in the farming economics system, individuals gain points in the trust and social capital systems.

The true benefits of building trust and social capital are realized when the broker participates in another system such as the finance system. If this person wants to participate as part of an informal lending group, other users will want to verify his or her trustworthiness. Due to social capital and trust ratings that were built up as a macadamia nut broker, the person now has additional leverage when trying to get access to economic capital through a microfinance institution. If this person has a large accumulation of positive ratings, others will feel more at ease about trusting him or her.¹⁶ When designing WishVast, we realized that all the systems are connected, and when we look at the connections, we have a better understanding of how to design and implement our technological solution.

Mashavu: Applying Regulation

Our team developed the Code of Ethics (CoE) for Mashavu during the Spring 2009 semester and conducted on-the-ground research in Kenya to assess its feasibility and validity and then refine it based on lessons learned. We discovered a number of complexities that make certain tenets of our CoE impractical. Expecting the Mashavu stakeholders to comply with the original CoE is not realistic due to common challenges such as lack of resources, education, large distances, different value systems, and highly contextual issues that vary from community to community.²² A key outcome of our team's fieldwork in Kenya was the realization that there are no rules regarding telemedicine in Kenya and the myriad laws and policies regarding healthcare are not enforceable. By applying regulation to Mashavu we can help to ensure a positive experience for the stakeholders and help build trust between the stakeholders of the system.

We are designing a closed-loop system in which all the stakeholders truly understand their role, have a direct incentive to participate in the process, and there are feedback mechanisms for accountability. The process and the user experience should be clear to the stakeholders and there should be specific checks and balances to ensure that the process is actually followed. Rewards for participation should be based on the quality of the "Mashavu experience" provided by the kiosk operator and experienced by the patient.

Tangible Time Indicator: An hourglass is used by the operator to ensure that they spend adequate time with the patient and fully complete the Mashavu examination. We found during our Kenya trip in the summer of 2009 that hospital patients wait many hours to see the doctor for a very short amount of time. By using the hourglass the patient has tangible evidence that the Mashavu operator is thorough with their exam, and not spending less time with the patient in order to accommodate more patients to receive more income.

Picture-based Sequence Chart: During each visit, the Mashavu operator will give the patient a picture-based sequence chart of how each visit to the Mashavu station will proceed. We designed

this hand-out with pictures so that those patients who are illiterate are included in the examination process. The sequence walks the patient through the exam including how each of the six measurements is taken. It allows the patient to check and question the Mashavu operator when they feel the process does not align with the handout. Having this hand-out serves a dual purpose of holding the Mashavu operator accountable for following the procedures and educating the patient on the testing process.

Mashavu Experience Rating: We found in Kenya during the summer of 2009 that the patients, after spending long amounts of time waiting to see the doctor, will rarely question or complain that the doctor spent too little time with the patient and therefore avoid giving the doctor any feedback on how their services could improve. Mashavu allows the patient to give feedback and share their expectation of Mashavu with the operator by means of a SMS text message. The rating opportunity helps the operator understand what their patients desire and gives them the opportunity to improve their business. Operators that perform the service well will be rewarded with incentives; however, those who have poor rating will be removed from the Mashavu network. This feedback mechanism ensures that the Mashavu operator is performing their role as needed and gives them the motivation and incentive to follow this role.

To keep all the stakeholders of the system happy means that each stakeholder must understand their role and have the motivation to fulfill this role. The accountability mechanisms and the feedback mechanisms provide the operator with the motivation to provide the service the patient desires. However, these mechanisms also need the participation of the patient to work correctly.

In closing the loop we focused mainly on keeping the patient satisfied with the service they receive from Mashavu. If the patient sees no value in Mashavu, they will stop visiting the kiosk, making the system and the operator's business unsuccessful. Therefore, our focus was on how to ensure that the patients receive better healthcare with the use of Mashavu so that the system can complete its overarching goals of socio-economic development, community health education, and improving access to healthcare.

WishVast: Applying Regulation

The overarching goal of WishVast is to help users quickly build trust and social capital to help alleviate poverty and, hence, WishVast needs to be more than just a simple social networking tool that connects people. Simply connecting people would not allow for the sustained building of social capital and trust, both of which play a very significant role in Kenyan society.^{15, 16}

When we were designing WishVast, we had to think of how those goals could be met. To do this, the ratings system was designed so that individuals could give quantitative feedback about the other users and the quality of their interactions. The ratings component is a critical piece of the WishVast system that allows us to regulate our users and their transactions and thus help meet our goals. With the ratings system, users are interjecting feedback and closing the loop on the WishVast system because, instead of just connecting with others and playing out a scenario, they are rewarding points based on their satisfaction with the transaction and the service provided by that person. Users will form groups and use WishVast for many different things, but in each scenario there is value in seeing the rating information.

For example, there are numerous farmers in Kenya that are trying to sell sugar cane. In order to get a fair market price for the sugar cane, many farmers prefer to coordinate with truck drivers to bring the sugar cane to larger cities where selling prices are higher. Figure 6 shows a scenario where these farmers are connecting with drivers to coordinate the distribution of the sugar cane. The communications are important, but the ratings upon completion of the transaction close the loop. The farmers will communicate via text message with the truck driver and vice versa so that the farmer's cane is promptly picked up and distributed, but upon completion of the agreed task, all parties will rate each other to describe their satisfaction with the interaction. This closes the loop on the system.

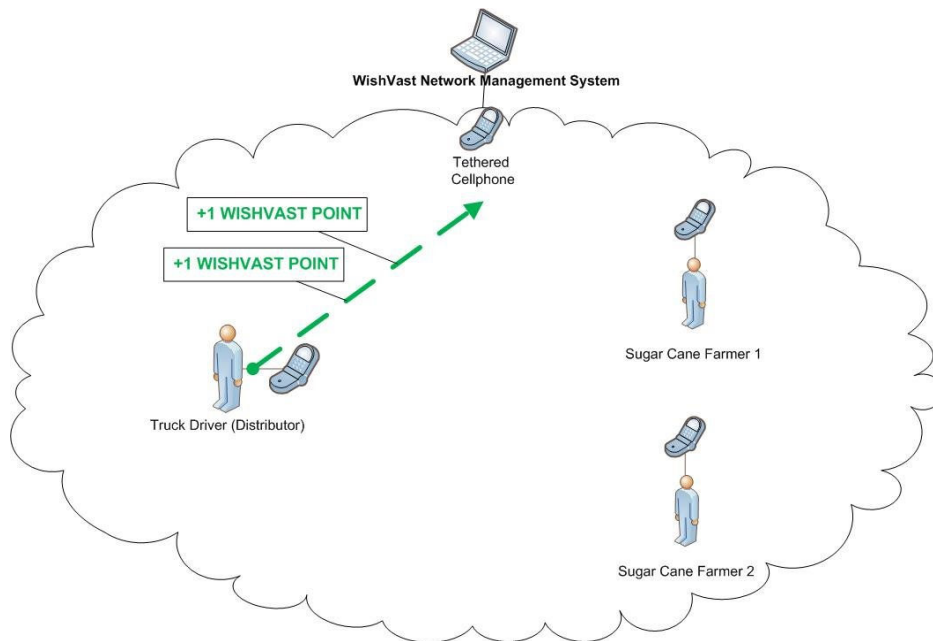


Figure 6: This diagram illustrates how a truck driver would assign ratings (points) to the sugar cane farmers upon completion of their interaction. The truck driver would send a text message to the WishVast Network Management System (the central computer on which WishVast is run) and the ratings would be assigned back to the farmers. The farmers would also have the opportunity to assign ratings to the truck driver.

Another scenario in which WishVast helps is in making employment decisions due to the fact that there are multiple people looking to hire qualified individuals for work and many people looking to find work.¹⁶ In a scenario in which a prospective employee connects with a prospective employer, ratings are also important. Both parties will communicate via text message to determine if there is a good match for the job, but upon making the connection, the ratings are an important factor to decide whether or not to accept the job. With WishVast, individuals can be matched up more effectively based on needs, skill sets, and prior experiences. Not only will a prospective employee wish to boast about his or her WishVast rating (the combined assessment of this person's trustworthiness based on past interactions), but a prospective employer will also want to show off ratings.

If a young woman is looking for a job as a house girl (one who helps with cleaning, babysitting, odd jobs and chores), she will want to be able to prove she is trustworthy. An employer looking at candidates will obviously prefer the most qualified candidate, and for a job like this, the most important qualifier is trust. This young woman will also want to look at the employer's rating, especially if he is male. With the unfortunate problem of sexual abuse in many developing regions, the woman will want to see that her employer can be trusted and that past house girls have rated him highly.

In all scenarios, WishVast was valuable because it helped all parties not only to find each other via the group aspect of the social networking platform, but also to rate each other. These ratings allow for users to quantify and build trust in a way that can be shared with others to explain that individual's reputation. Therefore, WishVast enables closing the loop on systems by allowing for individuals to rate each other, eventually accomplishing the goal of building social capital and trust. Without employing feedback by designing the ratings component of WishVast, it would not meet these goals.

Mashavu: Applying Multi-finality

Mashavu has four broad goals: improving access to healthcare, active community health education, socio-economic development through microenterprise, and transforming students into entrepreneurial global citizens. In addition to these overarching goals, the actors or stakeholders in Mashavu have their own individual goals. As shown in Figure 7, the actors include the Mashavu operator, the patients, the doctor, the investors, and the Mashavu team. We used the concept of multi-finality throughout the semester to improve Mashavu's design to meet the goals and needs of each user and to create motivation and incentives for each stakeholder to use the system.

Mashavu Operator: We found during our time in Kenya that government budget cuts to the healthcare system prevented hospitals from hiring more nurses. This has created a surplus of trained, registered nurses that are in need of employment. Placing a Mashavu system in a rural neighborhood in Kenya employs one of these nurses as a Mashavu operator. Because this nurse has found a job and accomplished his/her goal, the system achieves its goal of socio-economic development.

Patients: At one particular site, the closest health center to this community is about three kilometers away, and transportation to the center costs approximately the equivalent of one U.S. dollar. The patients could walk to the center, but this would take more than an hour. After arriving at the clinic, the patients may wait in line for a couple hours to see the doctor. This community needs a closer health center that will require less time to visit. By setting up a Mashavu kiosk in their neighborhood, they will have timelier and better access to healthcare. They will receive the advice and medical information through the nurse at the station and the doctors evaluating their cases. Therefore, we meet the patients' goal of receiving better healthcare and meet the system's goal of improving access to healthcare.

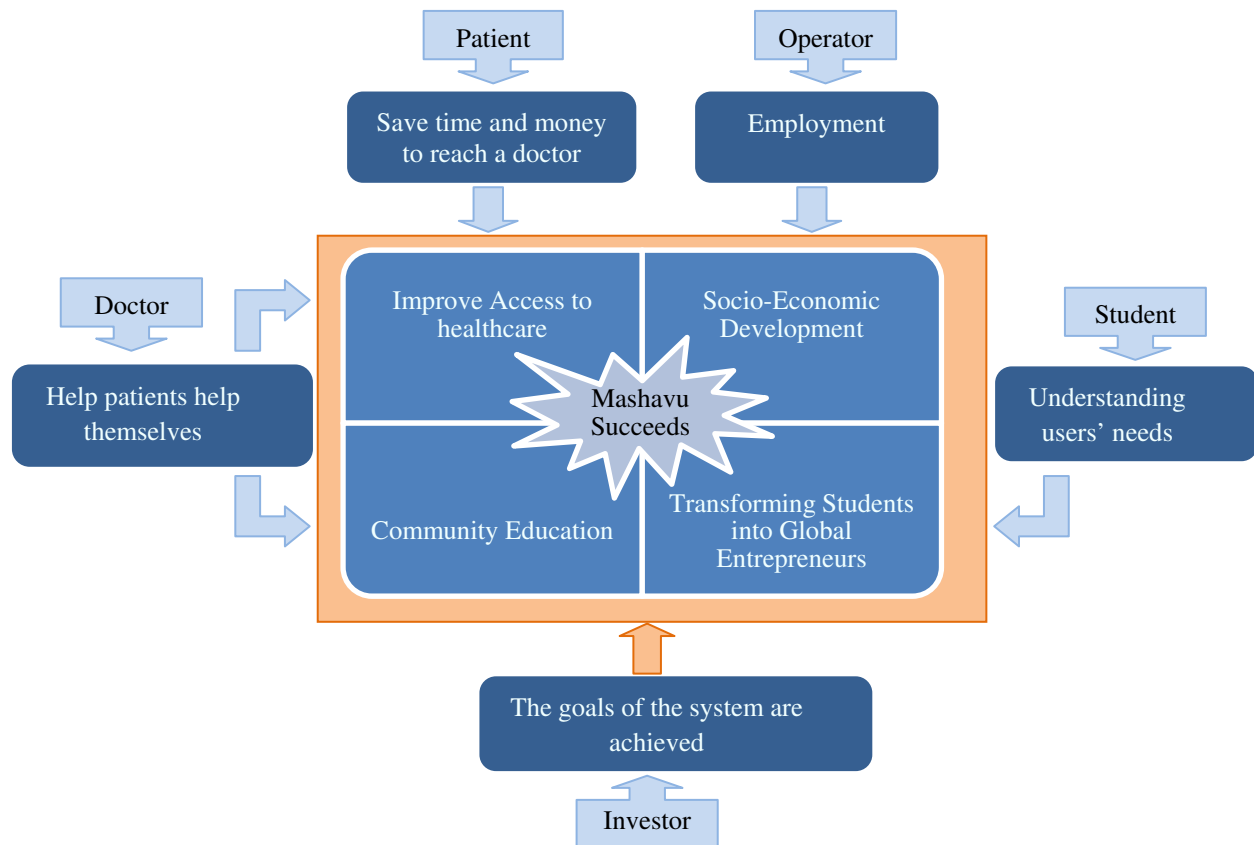


Figure 7: Goals of the various stakeholders of the Mashavu system

Doctor: Due to the high demand for the relatively few doctors, doctors can spend only a short amount of time with each patient. Patients rarely see the doctor for checkups, visiting only when they become ill. The patients often wait too long after the onset of symptoms to see the doctor, causing their problem to become more severe and complex. These doctors want their patients to better understand their health issues, but have too little time to educate their patients. A Mashavu station in the surrounding communities would alleviate the doctor from the long lines of patients to see and allow the doctor to spend more time educating the patients.

Investor: Although each investor in Mashavu may have personal goals in terms of economic and social bottom lines, overall each investor wants the system to succeed and achieve its goal.

Students: The students' goal throughout the semester was to understand the user better in order to help the system succeed. The essence of the system lies in understanding the business aspect of Mashavu; however, in order to understand the business, the students have to understand the context in which the business lies. It is through this critical thought process that the students are receiving an opportunity to develop into entrepreneurial global citizens.

With the application of multi-finality, we learned that we must understand the users and their goals, needs, and motivations for participating in Mashavu in order to help the system succeed. By focusing upon the users of the system, we developed and improved parts of Mashavu so that the system gives each stakeholder incentive to participate and accomplishes each stakeholder's goals while simultaneously meeting the goals of Mashavu.

WishVast: Applying Multi-finality

During the WishVast system design process, we employed the tenet of multi-finality by understanding the needs and goals of the various stakeholders and designing the concept of operations and the business model so that it meets all their goals and the goals of the WishVast system at the same time. We have discussed the business model considered for WishVast in a cooperative setting that demonstrates how we incorporated multi-finality into the design process.

In an effort to remain profitable, farmers join cooperatives, or informal groups, to gain the benefits of scale—including risk mitigation, increased market leverage, and access to financial resources for capital investment that can be used to purchase processing equipment, acquire storage space, and/or perform other value addition.¹⁵ Kenya has a largely agrarian economy and farmer’s cooperatives are extremely popular organizations throughout the country. Cooperatives typically charge their members a small fee on a monthly or biannual basis to sustain itself and provide other valued services. We want all the cooperative members to use the WishVast communication and rating system as it can lead to more beneficial connections and transactions within the cooperative as well as with external entities. Let us consider the needs and goals of the various stakeholders in this scenario.

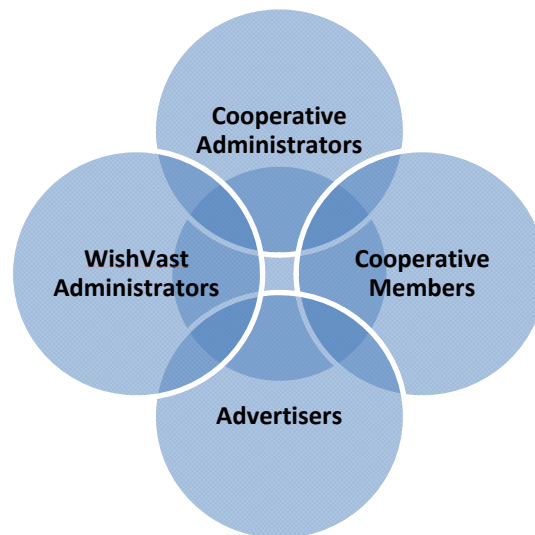


Figure 8: This diagram illustrates the stakeholders for which WishVast creates a win-win scenario. The center circle represents WishVast itself. All parties involved can better meet their goals, while WishVast also meets its goals.

Cooperative Administrator Benefits: Cooperatives already have dues associated with them, and it is very difficult for administrators to collect the dues from members. To use WishVast, members must pay WishVast fees. It is even more difficult for WishVast to go door-to-door to collect the WishVast fees. Instead of the users paying the WishVast fees individually, the cooperative can sign up all the members as users and pay (for example) \$1.00 for each user for every six months. The cooperative would then assess this additional \$1.00 fee to each of its members. If members do not pay, their WishVast account would be disabled and they would not receive messages or

ratings. Assuming that the cooperative members really want these messages and ratings, there is an incentive to pay their normal cooperative fees on time. Therefore, WishVast helps the cooperative collect its dues on time without having to go door-to-door and at the same time also collects its own fees.

Cooperative Member Benefits: Members of geographically dispersed cooperatives have a difficult time communicating with each other. With WishVast, they would all be in one group and would be reachable via SMS text messaging. This would help the members to communicate individually or as a group for the purposes of their coffee cooperative or also to communicate about other things now that they are connected. They can also receive advertisements from related companies (fertilizer, logistics, etc) on their cell phones for free and rate these companies after transactions. They can also look up the ratings accrued by the various companies and make informed decisions on their own business dealings.

Advertiser Benefits: If a cooperative group is connected with WishVast, advertisers can have targeted access to these members. Members of the cooperative could choose whether or not to opt-in to receive advertisements relevant to their group (e.g., fertilizer for coffee growers, etc.). By opting-in, the members of the cooperative could receive free SMS credit (paid by the advertiser) to use for whatever they want. The advertiser gets the benefit of only advertising to people for whom the ads would be relevant, and the only cost is the small fee of an SMS credit for the members (or potentially the WishVast fees for the members).

WishVast Administrator Benefits: WishVast administrators would be able to make money and continue operating WishVast as a sustainable business. The social needs would also be met because the WishVast users would be exchanging ratings to continue building social capital and trust, the ultimate goal for WishVast.

By applying systems thinking methodology, the design presents a win-win situation for all the WishVast stakeholders: cooperative administrators, cooperative members, advertisers, and WishVast administrators. With this design, many objectives are achieved via the same set of inputs. If only one stakeholder is not meeting their goals, the system will fail. This is made especially complex with a venture like WishVast, which has a double bottom line to be an economically sustainable business and also provide social benefits to rural communities. In order for the economic bottom line to succeed, human kindness and favors cannot be part of the design process; the robustness of the system must be rooted in financial sustainability.

Conclusion

Mashavu and WishVast are examples of technology-based social ventures whose concept of operations were made more robust by the application of the three key tenets of systems thinking: 1) employing regulation via feedback to ensure that the system is actually working; 2) defining systems by their interactions and their parts; and 3) understanding that systems exhibit multi-finality. These tenets of systems thinking were applied in classroom settings by allowing students to investigate the intricate complexities of the healthcare and poverty challenges in East Africa and design innovative solutions that meet the needs of the diverse stakeholders. The students' awareness that this was not merely an academic exercise but the system was actually being

designed for testing, implementation, and eventual commercialization in Kenya was a significant motivator.

The students learned many valuable lessons through participation in these ventures. By learning to understand the tenets of system thinking, the eventual system design will hopefully benefit both the end users and the students. By applying systems thinking to develop solutions, students were able to understand the context better and learn to employ regulation via feedback to ensure that the system is actually working, define systems by their interactions and their parts, and employ the concept of multi-finality to develop and articulate win-win situation for the various stakeholders.

The opportunity for students to actually get their hands dirty in designing and developing a solution allows for a new level of learning. Students saw this approach as more of a journey, and when dealing with the intricacies of understanding the systems, they began to see connections of these systems to their own lives, thus developing in professional as well as personal spheres. Through this experience, students developed as systems thinkers and learned to integrate ideas, concepts, knowledge, and evidence across disciplinary boundaries. They learned to explore diverse perspectives and dimensions of the challenges and attempt to design sustainable solutions by complementing conventional problem-solving methodologies with their own techniques derived from the systems philosophies that they internalized. The systems thinking approach to problem-solving provided the students in this multidisciplinary class a compelling context to advance from multi-dimensionality to multi-finality in their quest for designing sustainable solutions to address some of the most compelling challenges facing humanity.

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