Information to Iteration:
Using Information and Communication Technologies [ICT] in Design for Remote Regions

by
Kenfield Allistair Griffith
Master of Science in Architecture Studies. MIT, 2006

Submitted to the Department of Architecture
in Partial Fulfillment of the Requirements for the Degree of

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Signature of Author..
Department of Architecture
February 16, 2012

Certified by..
George Stiny
Professor of Design and Computation
Chair, PhD Program in Computation

Accepted by..
Takehiko Nagakura
Associate Professor of Design and Computation
Chair of the Committee on Graduate Students

Dissertation Committee

Stephen Graves
Professor of Operations Management
Leaders for Global Operations and Engineering
Sloan School of Management
Massachusetts Institute of Technology

Terry Knight
Professor of Design and Computation
Massachusetts Institute of Technology

Lawrence Sass
Associate Professor of Design and Computation
Massachusetts Institute of Technology

George Stiny
Professor of Design and Computation
Massachusetts Institute of Technology

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Abstract

Remote design comes with significant challenges. A major barrier to designing in remote regions is the lack of communication between designers and users. As a result, the lack of information flow leads to assumptions about the community's needs- an inherent weakness in the design process. This study examines the role that mobile phones play as a mode of communication between designers of products for communities in developing countries and the users within the communities themselves, in order to provide a better sense of context and environment. This study focused on the use of a communication software called mSurvey and its ability to create accessible feedback flows, that would otherwise be difficult to achieve within remote areas.

The investigation uses three case studies as examples. These case studies differ in location, design team, and distance. The first case study took place in Trinidad and Tobago and had software engineers as the design team. The second case study, in Nairobi, Kenya, consisted of architects, engineers, and Masters of Business Administration (MBAs) as the design team. The third case study, in Tanzania, consisted of a company of over 160 employees, whose job titles ranged from designers and engineers, to supply chain strategists.

The findings illustrate that, although each design task was different, there are similar challenges when designing for remote regions, specifically, developing countries. The solution to some of these challenges is the increased use of mobile technologies between designers and communities.

George Stiny
Professor of Design and Computation
Chair, PhD Program in Computation

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Contents

INTRODUCTION

This investigation studies the impact of community information and participatory feedback through information and communication technologies (ICT), on design solutions for developing countries. Design depends on context, whether in architecture, engineering, or systems design. Designers often negotiate and manipulate rules through problem setting and problem solving[1], which involves the act of embedding information through a series of iterative and reflective actions based on quantitative or qualitative sources of information. Designers extract bits of information from their own environment, as well as, the community's environments and experiences. Without the necessary information, designers often make incorrect assumptions. Using case studies, I investigate and illustrate the design process as accessing and sharing information through ICT. Specifically, this dissertation investigates mobile technology as a medium that helps designers quantitatively assess the design context when they collaborate with communities in remote regions, where the only communication technology available is a mobile phone.

[1] Herbert A. Simon, "Decision Making and Problem Solving" *Interfaces* Vol. 17, No. 5 (Sep. - Oct., 1987), pp. 11-31

Question:

> ***In what sense do you think that outside help is useful?***

Answer:

> ***We need outside help for analysis and understanding of our situation and experience, but not for telling us what we should do.***
>
> ***An outsider who comes with ready-made solutions and advice is worse than useless. He must first understand from us what our questions are, and help us articulate the questions better, and then help us find solutions. Outsiders also have to change. He alone is friend who helps us to think about our problems on our own.***

From a dialogue with activists of the Bhoomi Sena Movement in India
Source: *Seeds of Change* 1984

The excerpt above, dating back to 1984, illustrates the pervasive problem that still exists in the communication between communities and designers outside the community. The methodology used in this study quantifies design feedback from communities (end-users) throughout the design process. The assessment and evaluation mechanics of the design process are made possible through mobile phones and remote computing. The contributions made in the study are 1) a framework describing how information plays a significant role in the design process, when the designer is physically removed from the context of design; 2) a technological intervention called mSurvey, which uses information and communication technologies (ICT) allowing designers and communities to be actively engaged in the design process; and 3) a framework for developing designers' tacit knowledge, proximity to context, and conversations with communities (design users) as the keystone to enable participatory and collaborative processes of design.

This study shows that design context allows iteration and reflection to evolve naturally through participatory, collaborate design, and increased channels of communication. The work falls at the intersection of multiple disciplines, including - but not limited to- architecture, social science, design fields, computation, systems engineering, and management.

This study utilized and assessed information gathered from three separate case studies. The case studies were developed in three different geographical locations and design disciplines: 1) software design of mobile applications in Trinidad and Tobago; 2) infrastructure and architectural design of an Eco-san facility in Kenya; and 3) systems design, management, and business design in Tanzania. The mobile intervention is a channel for sharing information, which allows designers to "paint a picture" of the context through community intelligence, resulting in sustainable design.

The following chapters describe the framework developed in this research. The investigation includes data collected in Trinidad and Tobago; Kibera, Kenya; and

Tanzania; along with information received from the communities who interacted with the mSurvey technology. I outline the design approaches used by the designers in each region, their background, their experiences, and their familiarity with the regions. I describe a technology which was used directly in some case studies and repurposed for others, to illustrate the different levels of engagement based on the state of the design process, which was either “pre-design”, at the concept state, or “post-design”, at the utilization state.

In chapter 1 I give a brief history of technology in different design disciplines, and discuss how it has changed the role of industry and design process. I discuss tools such as CATIA, Revit, Skype and other technologies which have had impact on the design process as a collaborative environment. I discuss, with a few examples, the effect of technology and the globalization on the labor force. I also outline how mobile technology can benefit the design process in remote settings to enable a farther reach and an inclusive collaborative design process.

Chapter 2 discusses mSurvey, the technology developed in this study. I discuss the benefits of the technology and the advantages of using the methodology in remote design.

Chapters 3-5 discuss the framework in three remote locations as distinctive case studies. The case studies take place in Trinidad and Tobago; Nairobi, Kenya; and Tanzania; with over 8 designers ranging from architects and engineers, to Masters of Business Administration (MBAs) and a combined total of over 600 community members. The case studies include designing for a single community in Kenya, multiple communities in Trinidad and Tobago, and dispersed communities throughout Africa. I reflect on each case study showing the results of the methodology used and the implications of community intelligence in the design process for achieving sustainable designs. I discuss how information and communication technology (ICT) from multiple sources within a community can help designers develop deeper knowledge of their current users and potential users.

Chapter 6 discusses the benefits of information sharing using mobile technology, in collaborative design, which helps in developing appropriate designs. I argue, if the appropriate representation can be achieved and tailored for the stakeholders, the design results can evolve into greater success and provide greater sustainability in designs.

I conclude with Chapter 7, by extending the technology with three additional examples of using real-time information in the design process. The examples illustrate how the technology can be used, coupled, and scaled with other means of computation to bring greater understanding to the information gathered.

CHAPTER 1

Technology, Information, and Design

The constant relay of information from designer to community (customer) and community to designer often includes feedback loops for design validation until the design is "acceptable" (FIGURE 1.0).

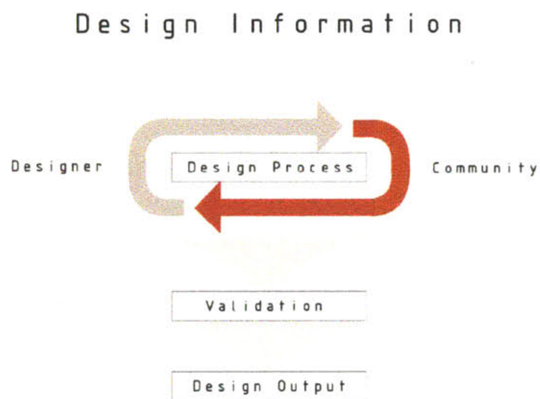

FIGURE 1.0: Information sharing in the design process

A design framework is difficult to apply in remote areas, where designers are physically and cognitively removed from the community's environment, with limited means of communication; which limit feedback loops and, ultimately, reduces design information.

Schön describes reflection as a process (1) to create a record of the designer's mental efforts, one that is "outside" the designer rather than vaguely in memory, and (2) to represent artifacts that can talk back to the designer.[2] Schön describes the process of a designer becoming an expert at the design process, as something internal that allows the designer to develop an understanding through constant delays

[2] Donald Schön, "The Reflective Practitioner" (1984)

of "pondering" and reflection. This process embraces continued negotiation between the designer and the design, in the designer's environment. During the design process, designers develop a methodology of iteration and reflection that challenges the designer's knowledge and queries her approach to a solution.

Due to the complexity caused by limited infrastructure, cultural barriers, and limited resources in developing countries, information is difficult to gather; especially in extremely remote and less developed regions. Proximity becomes non-existent, such that designers rely on technological interventions to reinstate some measure of proximity between designers and communities. Designers do not have the luxury of constant iteration and reflection due to the multiple design barriers outlined in this research. The interventions used in this study- mobile technology and remote computation- provide a framework to capture community information from multiple sources in parallel, at extreme distances apart. The aim is to, therefore, create "traditional" design settings and dynamic technological settings that mimic a formal design setting for remote regions.

As Saad (1994) emphasizes:

Collaborative design involves a significant amount of communication among design participants. Communication permits the sharing and exchange of design information during the design process.

Designing for an end-user requires increased communication channels among all designers, stakeholders, and the users of the design solution. Computation aids information processing for sustainable and holistic design interventions; allowing designers to design freely, despite the distance between designers and communities. The intervention re-establishes the expertise for which the designer is known and allows the designer to be actively aware of the states of reflection; offering a framework to develop quantitative rules for achieving the design goal.

1.1 Technology for Collaborative/Participatory Design

Technology has significantly revamped the workplace.[3] The role of technology has changed, and continues to change how designers interface with the active users of the design solutions. Email, digital images, simulation in the form of animation, digital plans, and three-dimensional computer environments,[4] have all changed the workplace environment and the relationship between the designer and the end-user. Designers use technology to represent designs that will be interpreted by the end-users, in order to get the necessary feedback to advance the design process. The convenience of technology has eliminated distances between the designer and the

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[3] Allen, Managing the Flow of Technology: Technology Transfer and the Dissemination of Technological Information Within the R&D Organization

[4] Yanni Loukissas, *Concepts of Design in a Culture of Simulation*

end-user, such that end-users of a designated design can offer objective and subjective feedback with the correct tools (means). The workplace setting has shifted from a static, linear operation to one that is highly agile, dynamic and participatory; where data and information are inserted into the design process by different stakeholders (FIGURE 1.1). Although this process can be observed in the context of design firms, such as Gehry and Partners, Foster and Partners, IDEO[5], and Arup[6], the description is tailored to a context where these kinds of technologies are available and accessible. However, even in these high technology environments, communication and the representation of information still pose a challenge and a significant problem. To improve communication and information flows that are appropriate for the design setting and in a remote context, both designer and end-user need to be equipped with the appropriate technology that will support the dynamics of a computationally-charged design culture, and the representation of information in the design.

[5] A Design and Innovation Consulting Firm based in the United States

[6] "...an independent firm of designers, planners, engineers, consultants and technical specialists offering a broad range of professional services. Through our work, we make a positive difference in the world.", http://www.arup.com/About_us.aspx

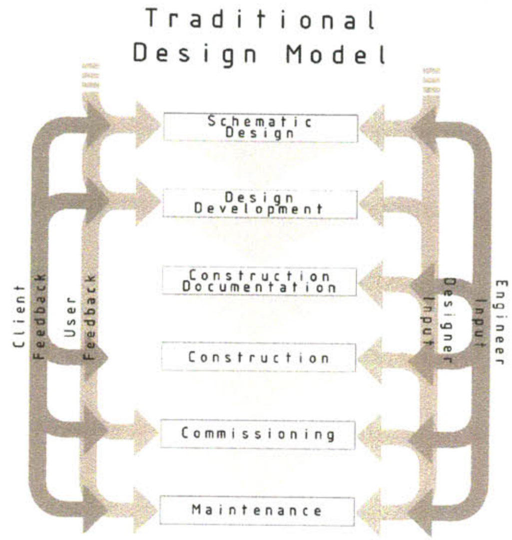

FIGURE 1.1: Design process experienced in current design firms

Collaboration: Stakeholder participation in the design process.

Stakeholders include designers, end-users, engineers, and business persons (FIGURE 1.2). All stakeholders are engaged in the design process through conversation, representation, and ideation. The role of the designer is to represent information in a way that will stimulate feedback from each stakeholder in order to create a successful and useful design outcome.

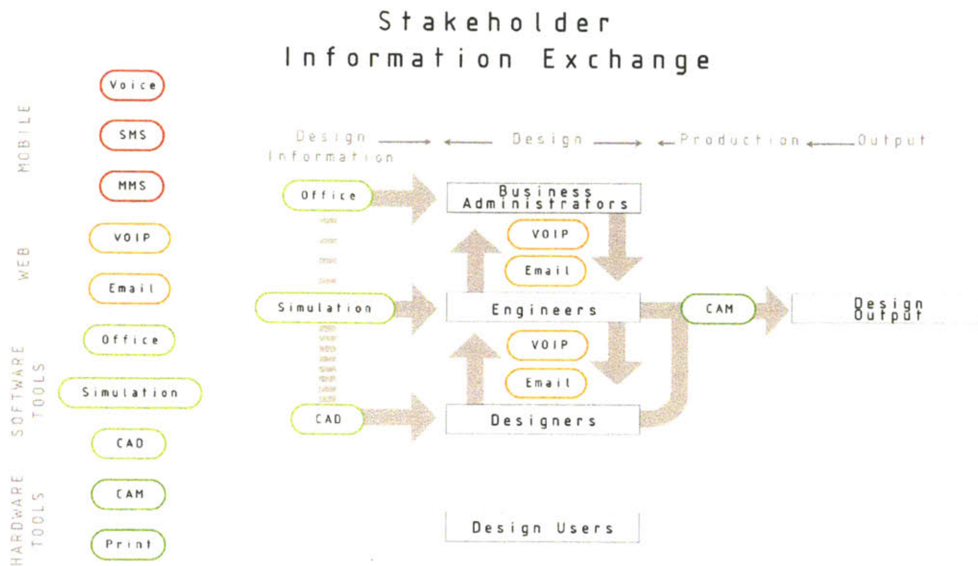

FIGURE 1.2: Stakeholder engagement

Information garnered from feedback is inserted into subsequent stages of the design. Design technology has created an ethos of stakeholder engagement through multimedia, allowing the designer to shape the design based on visual and verbal acknowledgment of the designs proposed.

Designer:

What is the designer's role?

The designer is considered to be an expert at the design process. The designer's role is to understand context, and develop a series of design investigations as problem setters. Designers look at the necessary variables and develop a cohesive understanding for identifying the design challenges. This is inherently difficult for the designer when she is removed from the context where the design will be utilized. Communication and computation enhance the design process and facilitates an environment for collaboration and collective sharing of information, which, in turn, creates a greater proficiency in developing appropriate solutions.

Community:

What is the community's role?

In conventional design settings, the community is responsible for engaging the designer with a set of needs and takes a very distant role as the designer develops design solutions. However, the community's role changes in remote settings. Community members are tasked with supplying context to the designer before a design can be considered a possible solution to community problems. This context allows for sustainable, community-driven solutions.

1.2 Design Technology: The Role of Technology in Design

The use of technology in design disciplines has helped designers save, manipulate, and represent data using computational tools. Ivan Sutherland[7] developed a solution that enhanced the relationship between machine and designers; this relationship is now a common part of the design process. In Sketchpad (FIGURE 1.3), a product of his dissertation, Sutherland's vision was more than a simple representation. It was a technology for creating different design states driven by data-input from the designer into the design system.

[7] Ivan Sutherland, Sketchpad: A Man-Machine Graphical Communication System (1963)

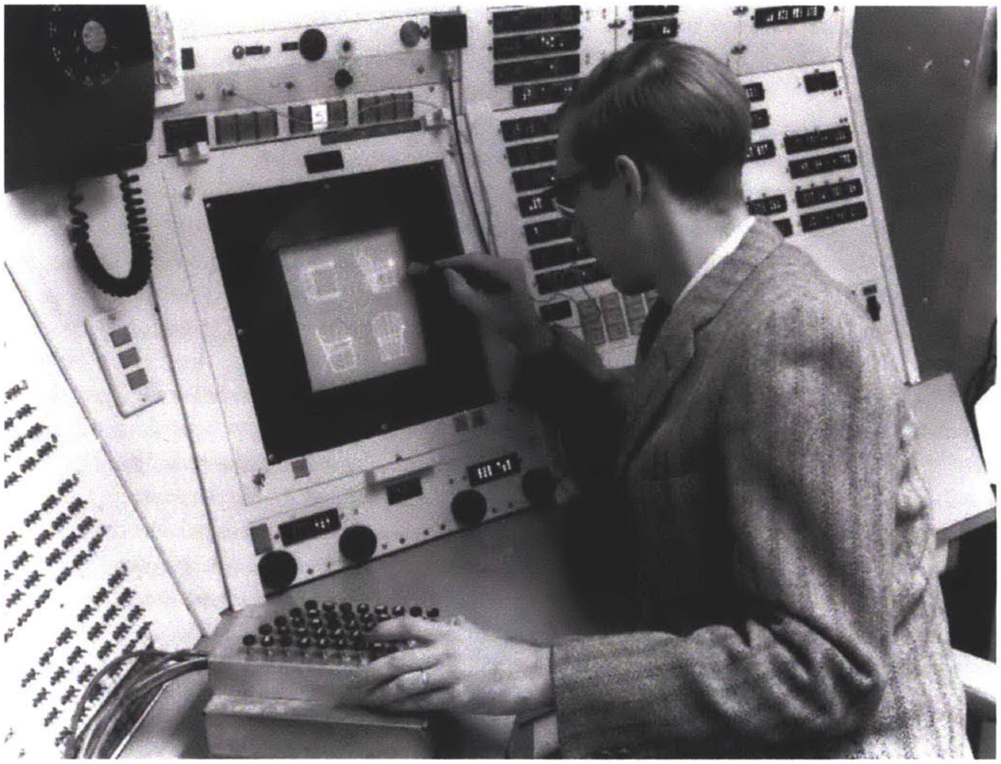

FIGURE 1.3: Sketchpad demonstrated on the console of the TX-2 at MIT (1963) (image from Sutherland's dissertation)

The computation developed in Sketchpad offered the means for the designer to use geometric data as the drivers of the design (FIGURE 1.4).

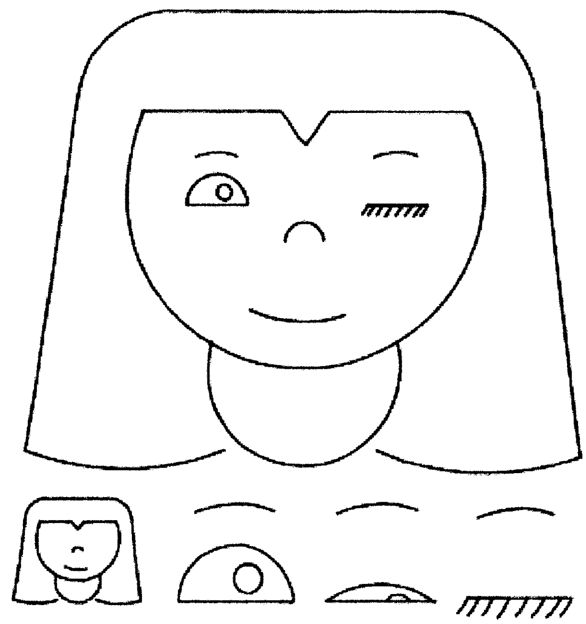

FIGURE 1.4: "WINKING GIRL AND COMPONENTS" (1964) (image from Sutherland's dissertation)

Sketchpad paved the way for computer-aided design tools which are predominantly used in the process of design, where data drives the design representation. It can be observed in tools such as CATIA[8], AutoCAD[9], Rhinoceros[10], Revit[11], and other computer-aided design tools.

The chart below (FIGURE 1.5) outlines the history of major types of communication and design technologies, and how they impact design. The chart highlights SMS and MMS to be included in the process and are both investigated in this study.

[8] Computer Aided Three Dimensional Interactive Application developed by Dassault Systèmes
[9] Computer Aided Design and Documentation Software developed by Autodesk
[10] NURBS modeling design software developed by McNeel and Associates
[11] Building Information Modeling software developed by Autodesk

1952	1963	1973	1982 – 1992	1985	1987	1994	1999
CAM CNC milling[1]	**CAD** Sketchpad[2]	**Email**[3]	**CAD** Autodesk Rhino[4]	**SMS**ǂ Short Messaging Service[5]	**BIM**[4] Building Information Modeling[6]	**VOIP** Voice Over Internet Protocol[7]	**MMS**ǂ Multi Messaging Service[8]
SOFT/HARDWARE	**SOFTWARE**	**WEB**	**SOFTWARE**	**MOBILE**	**SOFTWARE/WEB**	**WEB**	**MOBILE**
Physical production	Data manipulation	File sharing and communication	Documentation 3D rendering	General communication	Data sharing and manipulating	Meetings	File sharing and communication

[1] J. White, A proposed Mail Protocol, Request For Comment 524, Stanford Research Institute
[2] Ivan Sutherland, MIT
[3] An Automatic Machine Tool, Scientific American
[4] An interview with Bob McNeel, CEO and Founder
[5] Standard used by the Global System for Mobile Communications (GSM)
[6] Graphisoft
[7] US Patent 5,825,771
[8] Multimedia messaging service for GPRS and UMTS, Wireless Communications and Networking Conference, 1999. WCNC. 1999 IEEE
ǂ Innovative means of communication through mobile technologies

FIGURE 1.5: History of current technologies and proposed technologies in the design process

1.3 Context and culture

Context and culture are two important parameters of the design process. Both become evident through the ongoing access to community. Communities generate information about the environment and the ongoing changes which develop a sense of the inherent features of that community – the key variables that affect the design result. Communication and computational means allow designers to develop context through information offered by the communities. Designers "fine-tune" information, which is subsequently embedded in the design solution through visual representation or physical representation. The emphasis is placed on the presence or absence of information and the inferred knowledge that provide a clearer solution to the design problem. Information (new and old) aids the design; and can be increased through technological intervention.

Access to technology has allowed stakeholders to work from different locations and cultures, and to be part of the design process, despite geographic and cultural borders, in order to create greater knowledge about context. Context allows designers to design with greater freedom, by developing a design process that becomes "second nature". The internet, personal computers, voice over internet protocol (VoIP)[12], computer aided design software, and computer-aided manufacturing have all established a new culture of designing for global communities. Designers are actively engaged in a new technology culture to design solutions for seamless and sustainable integration in communities.

Although technology has allowed a new approach to design and greater participation in the collaborative environment, there are a significant number of communities in developing countries that lack access to these technologies, due to the lack of infrastructure. Walsh et al. shows how productivity increases with access to communication technologies such as email, which creates stronger ties between stakeholders.[13] The lack of communication technologies to improve the design process, where distance is a challenge, requires technology interventions that expand beyond conventional email use to allow engagement and participation in the design process.

Technology offers an opportunity for designers to reflect on data and manipulate designs for subsequent iterations. Technology increases participation to include many other sources of information, allowing the designer to gain a level of familiarity, which provides context for comprehensively understanding the communities and making informed design decisions.

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[12] Voice communication over internet protocol
[13] John P. Walsh, Nancy G. Maloney. In Distributed Work (2002), pp. 433-475

1.4 Technology, Design and Culture

Designers who design for cultures in developing countries are faced with the challenge of understanding how to design for resource-constrained communities. This challenge arises from the lack of technology that can be appropriately integrated into the design process. Designing for remote communities require a process of "designing from scratch" due to the absence of tangible design precedent.

Culture plays a significant role in design. A design that can be seamlessly integrated into a community is one that understands and relates to the community dynamics and is, therefore, one that successfully incorporates community feedback. Understanding community dynamics is not an easy process, especially when the designer is removed from, or has limited experience with context.

As Merritt Roe Smith, a Professor of the History of Technology at the Massachusetts Institute of Technology explains:

> *An invention, once introduced into society, is thus depicted as taking a life of its own. For example, the continuing improvement of the computer has followed a kind of internal logic (a logic embedded in its constituent material components and its design), so that each "generation" of enhanced computational sophistication has led, in a seemingly predetermined sequence, to the next.* [14]

There is a lack of tangible resources for designers to build upon and, therefore, designers need community engagement. Designers in remote areas are exposed to greater challenges not observed in cultures similar to their own. These challenges include: lack of communication strategies, lack of proper infrastructure to get around

[14] Merritt Roe Smith, Technology Determinism in American Culture, Does technology drive history?: the dilemma of technological determinism (1994)

the communities, lack of technological resources, and, at times lack of common understanding between the designer and the community. Designers are less likely to develop a local "know-how" to achieve successful designs if they do not understand the community for which the designers design.

Many definitions[15] of technology do not offer insight about the emergence of technology in developing countries where "know-how" becomes scientific knowledge and sparks development of creative technologies. The new ways of designing and developing technology in developing countries give historical context for next generations to build on. It is evident when designing for remote communities, technology plays a critical role in the design process, therefore, when designing for resource-constrained regions, the design solution often becomes a new technology for the communities.

[15] Whitley Richard, Task Type and Information Transfer in a Government Research Laboratory (1972)

CHAPTER 2

mSurvey: the technology

Mobile technologies are being used more frequently in developing countries offering services such as mobile banking[16] which allows unbanked citizens to purchase goods and store money in virtual accounts accessed and transacted through their mobile phones using Unstructured Supplementary Service Data (USSD) and Short Message Service (SMS) interfaces. These simple interfaces have significant impact on how information can be used and communicated by disperse sets of individuals, computer systems, and other forms of technologies. The mobile way of computing introduces new modes of communication and connectivity that were non-existent as recent as 7 years prior to this study.

Remote computing of information allows end-users to transmit bits of data from remote areas with limited infrastructure to be processed in areas where infrastructure does not pose a barrier. A collection of information can be processed and relayed back to the end-user in a light-weight easy to understand format such as text or even images, which allows the end-user to act upon the information as well as add to the collective body of knowledge for global access. End-users can choose to access information at their leisure, reducing the need for heavy processing on their local mobile phones with microcomputer processors. As a result, the mode of access increases information flow and increases the reach of communication once telecommunication infrastructure (cell towers) is in place.

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[16] The Economics of M-Pesa, Jack W., Suri T.

The internet has been present in Africa for over a decade; however the penetration suffers from the lack of local infrastructure and the associated costs of access. Internet in most developed countries relies on significant investment of infrastructure to allow access through local area network (LAN) cables or fiber-optic cables. Although connection through cables and physical lines allow speed of access, it reduces the potential reach of communication to those who do not have the means to connect physically which may require the need for a laptop. Most community members in developing countries make their first connection to the internet through thin-clients[17] and mobile phones connected through a telecommunication network. Telecommunication modes of connection allow connectivity, but the speed of data flow is still a challenge.

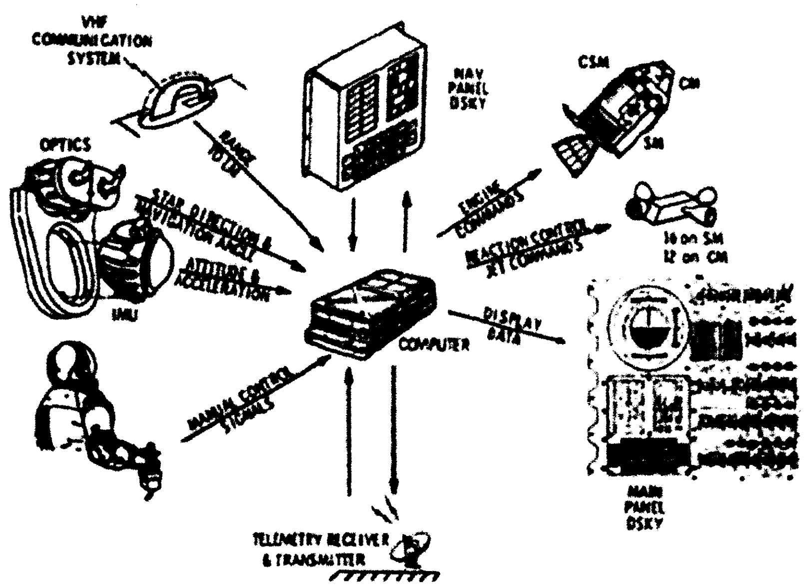
Considering the Apollo Guidance Computer (AGC) used in the early 1960s which was used to guide and control the spacecraft of the Apollo II mission, the computer specifications included a means of communication which enabled flight to moon. The data between communication networks offered a system that cohesively worked by sending information through satellite to be computed through different networks introducing new ways of distant communication.

Specifications of Apollo Guidance Computer

Instruction Set: Approximately 20 instructions;
100 noun-verb pairs, data up to triple-precision
Word Length: 16 bits (14 bits + sign + parity)
Memory: ROM (rope core) 36K words; RAM (core) 2K words
Disk: None
I/O: DSKY (two per spacecraft)

[17] Thin-client is a very basic computer usually without an optical drive and limited RAM (random access memory)

Performance: approx. Add time - 20us
Basic machine cycle: 2.048 MHz
Technology: RTL bipolar logic (flat pack)
Size: AGC - 24" x 12.5" x 6" (HWD); DSKY - 8" x 8" x 7" (HWD)
Weight: AGC - 70 lbs; DSKY - 17.5 lbs
Number produced: AGC - 75; DSKY: 138
Power consumption: Operating: 70W @ 28VDC; Standby 15.0 watts



CM system interfaces, Block II (Courtesy MIT Instrumentation Laboratory Report, Graphic Number R700-1-52)[18]

When compared to the specifications of a simple Nokia 1661[19] mobile phone it becomes evident how easy it might be to extrapolate the potential communication ability one can dream up with the introduction of mobile communication. It is not to say that mobile technology will be provisioned as a technology for a trip to the moon, or maybe it will; but to introduce the ability to communicate information to

[18] Hall, Eldon, Journey to the Moon: The History of the Apollo Guidance Computer, Washington: American Inst of Aeronautics, 1996.
[19] Nokia's specifications for their Nokia 1661 manual

be processed in multiple locations or multiple time zones from a mobile device allows many events to occur concurrently or asynchronously allowing access to information and providing context to remote regions.

Specifications of Nokia 1661

Size: Dimensions: 108 x 45 x 13.55 mm; Weight: 82g; Volume: 58.00 cc (cm3)
Display and 3D: Main display- Size: 1.8"; Resolution: 128 x 160 pixels, Up to 65,000 TFT[20]
Keys and input method: Numeric keypad; Large keys - easy to use
Memory: 8 MB internal memory
Power: BL-4C 860 mAh Li-Ion battery; Talk time (maximum) – GSM (Ectel) 4 hrs 10 min
Standby time (maximum) – GSM (Ectel) 475 hrs
Operating frequency: Dual-band EGSM 900/1800, GSM 850/1900
Messaging
SMS with support for concatenated SMS for long messages
SMS storage: up to 250 messages on phone
Speed dialing for SMS sending
Multiple SMS deletion
Common inbox for SMS messages
Distribution lists for messaging
Chat via SMS

As of 2010, 70.1% of the population in the developing world subscribed to mobile telephone services, up from 23% in only 5 years ago.[21] The majority of the community members owned simple Nokia[22] phones, Nokia 1661 being the major choice. The simple model phones allow the community members to participate in voice conversations and to send text messages (SMS) within peer-to-peer networks.[23] Unlike major telecommunication operators in the United States which provide subscribers contract agreements and post-paid options to maintain

[20] Thin-film transistor
[21] ITU World Telecommunication/ICT Indicators Database, Accessed January 2012: http://www.itu.int/ITU-D/ict/statistics/index.html
[22] Nokia is a major telecommunication brand headquartered in Finland that develops and sell telecommunication devices
[23] Friends and colleagues

telecommunication services, in the regions discussed in this study, most community members owned pre-paid services on their phones as Pay As You Go service.

The definition of SMS[24] is short message service. This protocol is used mainly for text communication between mobile to mobile phones (handsets for peer-to-peer communication). The format is typically under 160 characters in length to relay quick snippets of information between users. 160 characters was however not a technical limitation of the mobile phones, however a standard which was developed by Friedham Hillebrand in 1985 who thought 160 characters were sufficient to transmit a text message via telephony.[25] At time of study, SMS communication was considered the most common mode of communication between peer to peer. Unlike email that requires data connection and a way to access the internet, SMS information can be transmitted through telecommunication protocols making the mode of communication accessible to anyone with a mobile phone.

The technology used throughout this study is a SMS software called mSurvey connected to local telecommunication infrastructure (transmit data through cell towers) (FIGURE 2.0) in the regions of the three case studies. The local connection was important to increase the communication rate of messages from end-user to designer.

[24] European Telecommunications Standards Institute (1985)

[25] Milian, Mark. "Why text messages are limited to 160 characters" Los Angeles Times on the Web 3 May 2009. 02 Feb. 2012 < http://latimesblogs.latimes.com/technology/2009/05/invented-text-messaging.html>

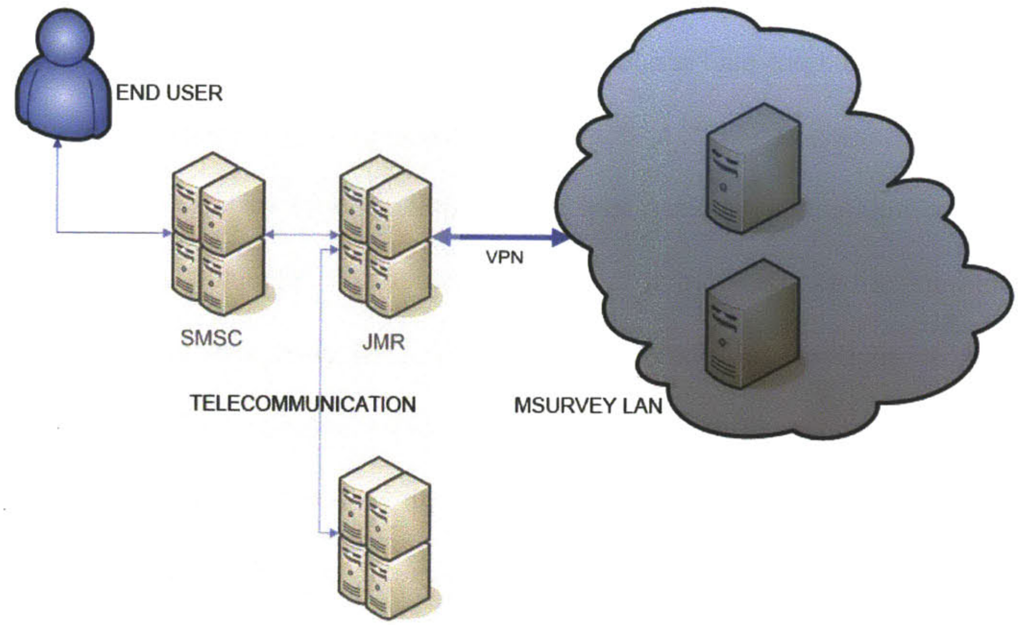


FIGURE 2.0: The architecture between mSurvey and local telecommunications

mSurvey is a novel survey methodology for collecting data from communities in developing countries or other regions that typically are very difficult to access. The industry standard for communicating with low-income populations remains heavily reliant on paper-based, in-person surveys. Analysis of other methodologies reveals that mSurvey provides a time, cost, and reach advantage over these alternative methods (FIGURE 2.2).

While other survey methodologies are necessary for some kinds of in-depth evaluations, mSurvey provides instant data collection from remote regions for every day decision-making and trend spotting. mSurvey can be deployed virtually to collect real-time responses from thousands of individuals—with the capability to handle 200 messages per second at time of study—eliminating the need for in-person surveys, travel and wage expenses, and time spent on data compilation. Moreover, without formal addresses, it is difficult to survey the same individuals over a period of time, which mSurvey can easily achieve for as long as the respondents keep the same phone number.

mSurvey's greatest impact comes from facilitating and improving the way designers, engineers, and decision makers engage with remote communities. The technology offers the ability for many stakeholders to provide critical feedback on decisions that will impact ongoing development and understanding their own communities when the information is shared.

mSurvey was developed on a server in the US connected to telecommunication servers in Trinidad, Kenya, and Tanzania (FIGURE 2.0). The connection was made possible through secured virtual network protocol (VPN) as a security standard to allow the relay of text data from telecommunication towers through Short Message Peer-to-Peer protocol and Short Message Service Center protocol all made possible through an internet protocol (IP). All traffic was handled through Short Message Peer-to-Peer (SMPP) Short Message Service Center (SMSC) protocols. When end-users sent a message using their mobile phones to a number mapped to the software, the message would be routed to the software and parsed accordingly. The software was written in PHP, Python, MySQL, and open-source applications. When messages were delivered to the mSurvey system, each message was associated with a Mobile Subscriber Services Digital Network Number (MSISDN) and aggregated based on responses. Each MSISDN is a parameter that identifies the user and possible location. The technology uses a cloud-based (remote) infrastructure written on Linux

Operating System that supports scaling across geographical borders, countries, and in very remote regions with limited infrastructure.

mSurvey went through a series of iterations before its current version. The software was written to create questions that had logical structure which included:

multiple choice questions: the end-user would return (text) a choice based on a few options they would see on their mobile phones

all that applies questions: the end-user would return multiple answers from a few options they would see displayed on their mobile phone

open-ended questions: this was a direct question which the end-user would reply with their thoughts about the question

branching questions: the end-user would respond to a choice of a question which would branch to different questions based on their response (FIGURE 2.1)

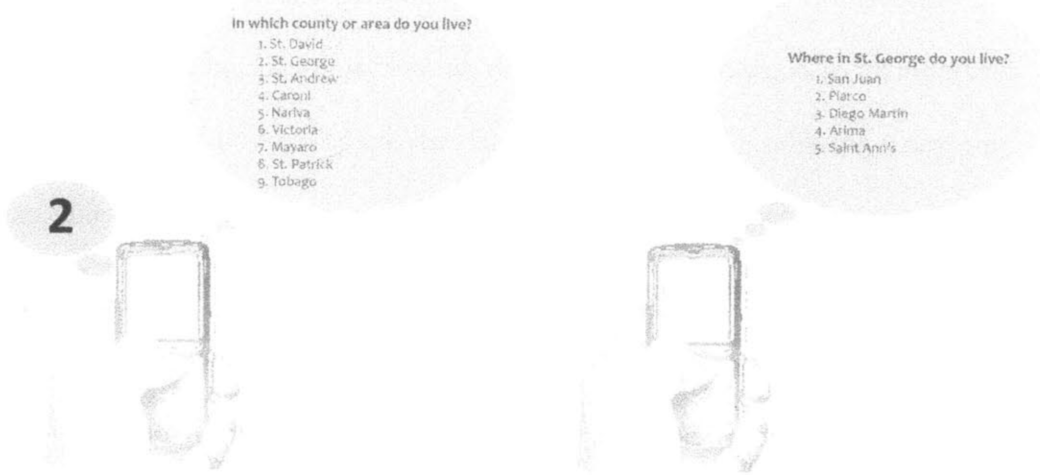


FIGURE 2.1: Branching logic of mSurvey

mSurvey facilitated a bidirectional communication between the designers and their end-users in the case studies. mSurvey was used as a communication channel to gather information from the communities in which the design intervention was needed. The information gathered from collective sources was combined throughout the design process to build context about the community and the environment for the designers. mSurvey served as a framework to gather information in real-time to mimic "conventional" design settings and create a design dialogue between designers and end-users. mSurvey allows designers to iterate and reflect with the community members for collaborative and participatory feedback.

As discussed throughout this study, the designers were all removed from the communities physically, culturally, and technically and needed to gain access to increase necessary communication. The technology works by allowing community members to "opt-in" to participate with their mobile phones, at which point they become a stakeholder in the design process offering feedback and ongoing input.

The designers in the case studies all had community liaisons who assisted with the development of questions and logistics to remove language and cultural ambiguities.

mSurvey provides a time, cost, and reach advantage over other methodologies (see chart below). The technology processes messages at a rate of 200 messages per second allowing many community members to participate in offering ongoing feedback and design assessment throughout the life of a project. Many other techniques of getting end-user feedback stem from participatory rapid (rural) appraisal include communities offering snippets of information about context independently, to ethnographic of having longer engagements with the community, most often through a living arrangement. Each mode therefore has its advantages and disadvantages; some which include cost (FIGURE 2.2). Most of these approaches are very extractive with limited engagement of the end-user as the drivers of the information as design input.

	PRA	Survey Research	Ethnographic Research	mSurvey
Duration	Short	Long	Long	Short/Long
Cost	Low to medium	Medium to high	Medium	Low
Depth	Preliminary	Exhaustive	Exhaustive	Preliminary/Exhaustive
Scope	Wide	Limited	Wide	Wide
Integration within community	Multidisciplinary	Weak	Weak	Multidisciplinary
Interview structure	Flexible, informal	Fixed, formal	Flexible, informal	Flexible, informal, formal
Direction	Bottom-up	Top-down	Not applicable	Bottom-up
Participation	High	Low	Medium to high	High
Methods of surveying	Different tools	Standardized	Different tools	Mobile phones/real-time analytics
Major research tool	Semi-structured interview	Formal questionnaire	Participant observation	Mobile phones and internet viewing
Sampling	Small sample size based on variation	Random sampling, representative	None	Random, representative, small sampling
Statistical analysis	Little or none	Major part	Little or none	Major part
Formal questionnaires	Avoided	Major part	Avoided	Major part
Organization	Non-hierarchical	Hierarchical	Not applicable	Non-hierarchical
Qualitative description	Very important	Not as important as 'hard data'	Very important	Semi-important
Measurement	Qualitative or indicators used	Detailed, accurate	Detailed, accurate	Detailed, assessment indicators, accurate
Analysis/Learning	In the filed or on the spot	At office	In the field and on the spot	Real-time, global access
Follow-up frequency	Low to medium	Low	Not applicable	High

FIGURE 2.2: mSurvey comparison to other survey methodologies

The methods illustrated in the chart were compared based on paper-based approaches of getting feedback from end-users. In comparison, the mSurvey technology enables end-user engagement using mobile phones and can span across each methodology illustrated in the chart.

CHAPTER 3

Software Design and Development for Smartphones: A Trinidad and Tobago Case Study

In the following case study mSurvey was used to generate frequent feedback from a set of disperse fishing communities throughout Trinidad and Tobago. The feedback was used as design input in the development of a mobile software suite of applications.

According to the Fifteenth International Conference of Labour Statisticians:

"The informal sector may be broadly characterized as consisting of units engaged in the production of goods or services with the primary objective of generating employment and incomes to the persons concerned. These units typically operate at a low level of organization, with little or no division between labour and capital as factors of production informal sectors"

Many of the challenges which hinder the design and development of infrastructure and sustainable economic solutions of various informal sectors in the Caribbean arise from inefficient and ineffective information and communications strategies. However, mobile communications penetration levels are extraordinarily high, even among low-income Caribbean communities[26]. The presence of such mobile communications presents many opportunities for increased efficiency and effectiveness of information. However, designing appropriate mobile solutions for low-income Caribbean communities is challenging.

This case study took place from September 2010 – October 2011 and was focused on how mSurvey was used to enhance the flexibility and iterative process of agile software design, a methodology introduced by Gerald Weinberg in the late

[26] Telecommunication Authority of Trinidad and Tobago, 2009

1950's.[27] The agile software model, defined by its inherently flexible nature, is well-suited to the design and development of mobile applications for low-income earners in informal sectors. The agile software model is participatory, as well as, iterative in nature, which provides the opportunity for designers and target users to learn with, and from, each other through repeated cycles of contemplation, articulation, exploration, assessment and acceptance. However, the ongoing engagement in the design and development process requires a great deal of time, as well as, other resources, for both users and designers to interact productively.

This case study provides an account of the current inefficiencies and challenges when designing for informal sectors in the Caribbean. The case study also provides resource-efficient design strategies used by a team of Caribbean mobile application developers to engage with a community of low-income earners in order to facilitate agile software design and development, in a resource-constrained context. The process of design is incremental and depends on collaboration between design developers and users, as well as the participation and feedback for the subsequent design stages. Due to the unconventional context experienced by the designers, mSurvey enabled the frequent engagement between designers/developers and the communities. mSurvey was used to facilitate frequent feedback about the design and development of new mobile applications designed by the team for use by the communities. mSurvey was an important channel, providing important insights into the replicable process of agile mobile application development for the target users.

[27] Gerald M. Weinberg, as quoted in Larman, Craig; Basili, Victor R. (June 2003). "Iterative and Incremental Development: A Brief History". *Computer* **36** (6): 47–56.

3.0 The Caribbean: Trinidad and Tobago

The Caribbean consists of approximately 40 island nations, situated between the Caribbean Sea and the Atlantic Ocean (FIGURE 3.0). This case study was conducted on Trinidad and Tobago, which has a diverse mix of cultures, as well as ethnicities, and includes the influence of Africans and Asians (East Indians and Chinese). With a population of 1.3 million, a land mass of roughly 4828km^2, Trinidad is divided into 8 major regions, with about 35 different towns/cities. The reader should note the diverse set of users the designers had to engage, which gave rise to challenges in designing a solution that fit well within the societal constraints.

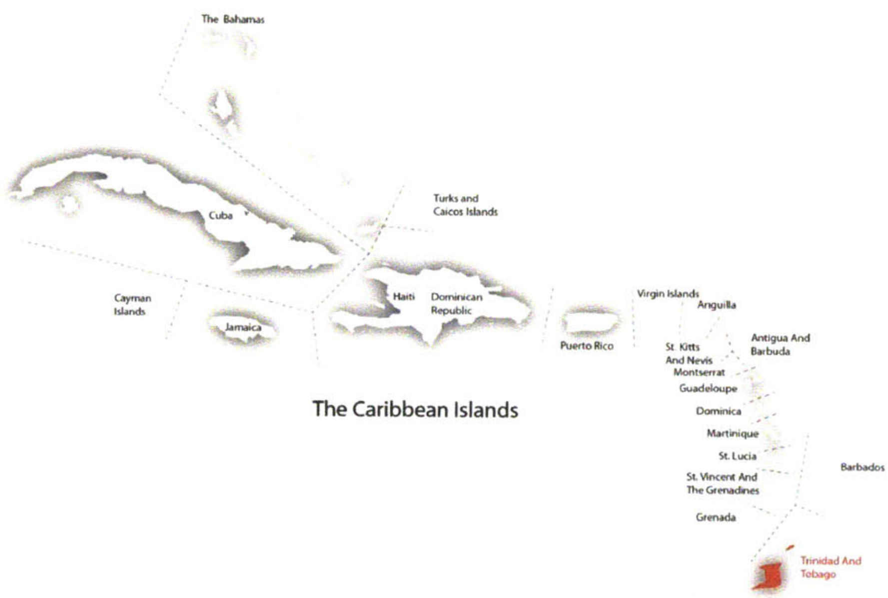


FIGURE 3.0: Caribbean islands showing location of Trinidad and Tobago

Economy of Trinidad and Tobago

The economy of Trinidad and Tobago is quite diverse; however it is predominantly based on the presence of oil and natural gas. Other economic drivers are industry, agriculture, and fishing. Trinidad is known to be one of the leading gas-based exporters. These exports include methanol, ammonia, and liquefied natural gas. However, the production of oil has declined, impacting the general rate of production, affecting the GDP of the country. As a result, the reduction in oil production opens up opportunity to concentrate on other revenue streams such as fishing, which is the driver of the second largest food group in the island.

3.1 Designing in Fishing Communities: Design Context

The designers in this case study were all computer scientists and electrical engineers from the University of the West Indies (UWI).[28] They were tasked with developing new mobile applications for fishing communities. Stakeholders for the design interventions would include the fishing communities, the coast guard, the telecommunication companies, other UWI departments, and the general public. There were a total of 6 designers who resided in the capital district of Port of Spain. Over a 2-year period, November 2009 - October 2011, the team of designers investigated an approach to develop greater stakeholder capacity in the Caribbean for improving their mobile software design. The designers pursued two goals: 1) opportunities for the design and development of innovative mobile-enabled services for the fishing communities, and 2) a way to provide related empirical data and

[28] University of the West Indies, St, Augustine, Trinidad and Tobago

analysis to inform Caribbean policy and regulation on ways to engage informal sectors.

The users were fishing communities that resided in multiple regions, stretching across the island from Toco, which is the northeastern tip of Trinidad, to further southwest at Claxton Bay (FIGURE 3.1). These areas are mainly made up of "fisher folk" who make their living from selling their daily catch directly to members of the community or the capital of Port of Spain at a bargain price. Their profits do not provide a living wage and are therefore not sustainable, and do not quite justify the time commitment invested in being on the ocean all day; nor are the profits sufficient for them to advance to a higher income bracket. It is believed that profits are constrained by significant bargaining; and, therefore, the fishing communities have become one of the poorest communities on the island.

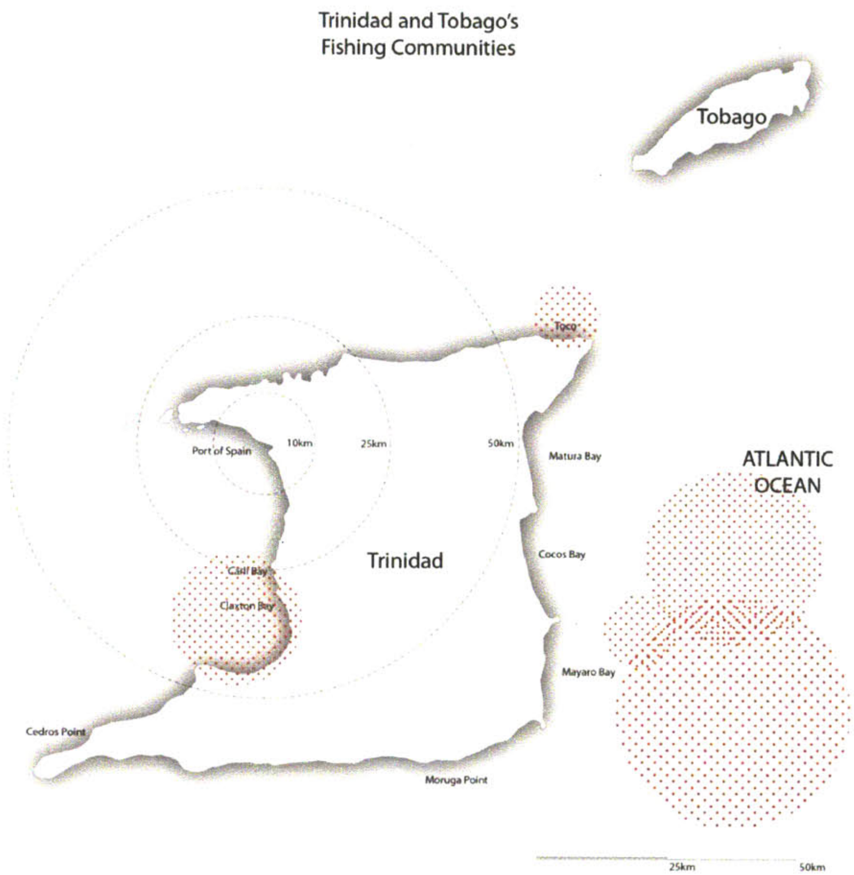


FIGURE 3.1: Island of Trinidad showing fishing areas Toco and Claxton Bay

The designers investigated ways to improve the profits of the fisher folk. The design decision was to introduce new technologies into the community. However, like many approaches to new design concepts or technologies, the designers saw a challenge with the learning curve of the community and, therefore, needed a clear and efficient participatory approach to engage the community in the design process. Although the designers and engineers were from Trinidad, they were still removed from the lifestyle of the fisher folk community, and were, therefore, challenged with developing a cost effective, non-intrusive, and novel methodology of engaging the community throughout the design cycle.

3.2 The Engineers' Approach to Designing Mobile Software for Dispersed Communities

As noted by the designers:

"mFisheries is a suite of mobile applications developed for men and women working in the fisheries sector, from small scale fisher-folk, processors and retailers, to wholesalers and consumers. Through the use of a smart phone, users can get information on daily fish market prices, GPS navigation-there is also a compass-, first aid companion, SOS emergency signal..."

UWI Designers and Engineers

This case study focused on how mSurvey was used in the design and implementation of a mobile software suite called *mobile fisheries*, mFisheries. To accomplish the design task set by the designers, the mFisheries software suite needed to be developed and deployed on mobile phones which included the following applications:

Got fish, Need fish

An interactive application which facilitates the broadcast of notifications from individuals who have fish for sale *(Got Fish)* and those who wish to purchase fish *(Need Fish)* (FIGURE 3.2). It displays matches between those who have and those who need the same type of fish, and facilitates a phone call or message between parties interested in pursuing a sale. ***Prices*** displays the most recent prices of fish in the Port of Spain and Orange Valley markets, as determined by the National

Agricultural Marketing and Development Corporation, NAMDEVCO, of the Government of the Republic of Trinidad and Tobago. The application is searchable by 'Fish Market' (Port of Spain or Orange Valley) or 'Fish Type'.

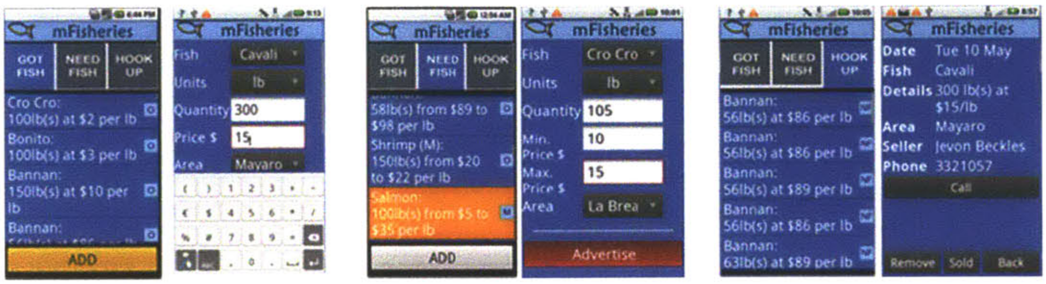


FIGURE 3.2: GOT FISH mobile application (image provided by designers)

SOS

The emergency response system allows fisher folk to signal the Trinidad and Tobago Coast Guard anytime someone is in distress. By the click of a button, immediate pre-defined notifications are sent in the form of email and text messages, and a voice call to the Trinidad and Tobago Coast Guard (TTCG) automatically initiated.

GPS

A position tracking system which periodically records, on a Web server, the date- and time-stamped location coordinates, for retrieval in the event that a fisherman is thought to be lost at sea. This tracking is triggered when the mobile phone is detected as having left the 'geofence,' defined by the land boundary of Trinidad. mFisheries navigational and safety support also includes a ***compass*** and user-controlled GPS position logging and retrieval tool.

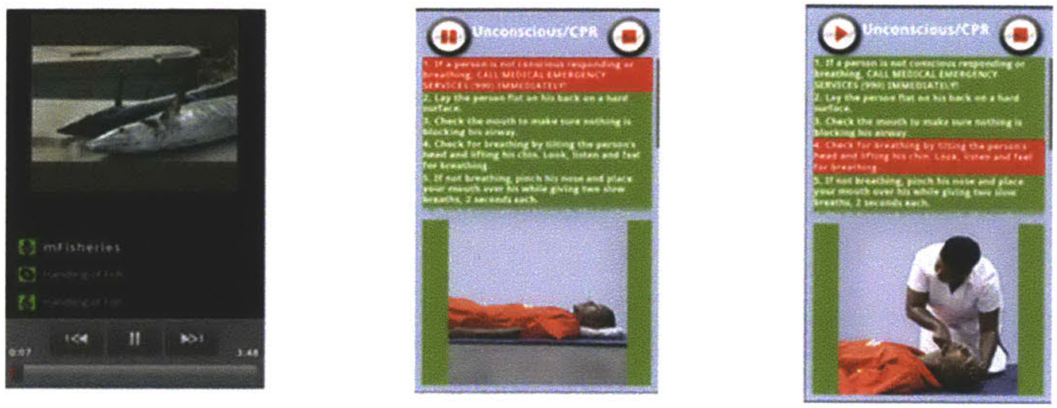


FIGURE 3.3: First aid mobile application (image provided by designers)

FIRST AID

Multimedia Training Companions deliver key points from eight training modules (*Unconscious, Choking, Back Injury, Bleeding, Heat Stroke, Exposure to Cold, Sea Sickness and Shock*) offered by the Caribbean Fisheries Training and Development Institute. In the mobile Training Companion (FIGURE 3.3), oral instructions are synchronised with text and images to describe the steps to be taken in case of a variety of emergency scenarios. Multimedia controls for stopping, pausing and playing the training content are included. ***Tips*** delivers audio podcasts on themes such as emergency maintenance, fishing methods, handling of fish, preparation for sea, rules of the road and survival at sea. The ***Camera*** tool facilitates the reporting of matters of concern by the fishermen.

The design team created mFihseries with two major questions in mind:

1. *How can the ubiquitous mobile phone be used to solve known inefficiencies in communications which impose unnecessary limitations in earning capacity and social development among low-income Caribbean earners?*
2. *How can Caribbean capacity (stakeholder interest) be built to engage communities of low-income earners in order to collaboratively design, develop, deploy and evaluate applicable mobile solutions?*

The additional challenge the designers were keen to mitigate, was teaching the end-users how to play an active role in the design process. Traditionally, the end-users, who were from fishing communities, were not familiar with the "back and forth" of the design process. They were also not aware, or could not clearly acknowledge, they had the freedom to advise when they did not like the feel, look, or utilization of the mFisheries design solution. The users were not aware that their input could serve as a design change, which in turn would help them utilize the end design more effectively, or become more engaged and attached to the end result.

The designers were therefore responsible for allowing the end-users to take ownership of the design as critics. The users were instructed to investigate, and be conscious users of the product at hand, in order for the iterative design process to succeed.

Software Design Models

Prior to the utilization of mSurvey within the design process of the mFisheries software suite, the designers were challenged with the problem of developing the appropriate software suite for a vast set of users, despite the commonality of the fishing community. The designs had to be gauged for aesthetics, clarity, ease of use and many other features discussed later in this case study.

The designers had two familiar design models for designing the mobile application for the fishing communities: waterfall design model and agile software design. A brief description is provided of each design approach to provide context of the challenges the designers faced.

Waterfall design model

In 1970, Winston Royce presented a description of the waterfall design model (Royce 1970) and described the inherent flow, which some see as a direct mapping of the manufacturing and construction processes. The waterfall software development (FIGURE 3.4) takes a very steady approach of steps and phases to an end product with limited flexibility for revision and change. Unlike the designs of today, which utilize iteration and constant feedback loops, the waterfall model is very sequential with limited feedback loops. Therefore, feedback loops for design iteration would be found in a later development stage, after implementation, which is considered too late to affect the design process.

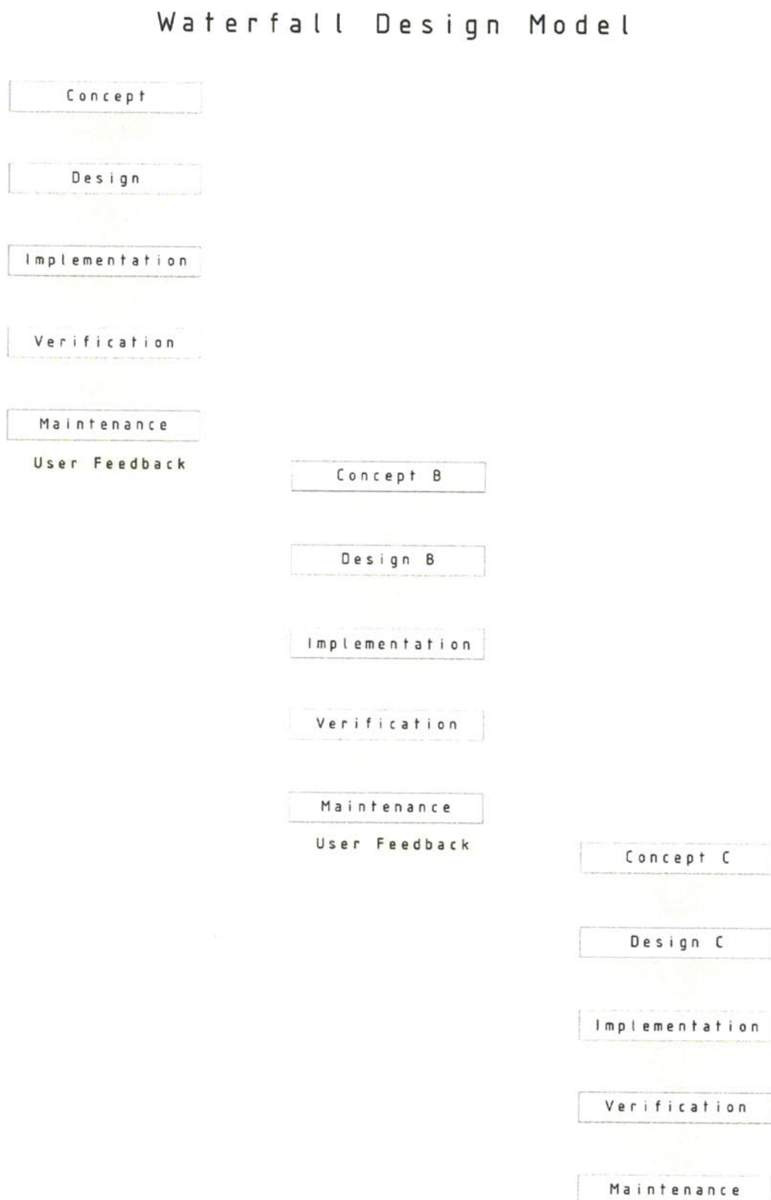


FIGURE 3.4: Waterfall design model

Concept: *"The problem" or the idea for the software design.*

Design: *How the designers approach the problem to develop the appropriate design solution. This may include software design patterns taken from previous projects, or known algorithms or solutions that deal with the logic of the problem rather than the user experience.*

Implementation: *Developing the necessary code that correlate with the design requirements and specification.*

Verification: *Testing if the solution meets the needs of the concept; "does it work?" This usually requires a few tests written to manage the robustness or optimization of a solution.*

Maintenance: *Unfortunately, this is where feedback loops come into play once the software is deployed and utilized, which makes it extremely difficult to input design changes that reflect end-users' experiences.*

The waterfall design model exemplifies the difficulty with gaining community feedback, as it is perceived to be a completely closed system, where the designers develop solutions in a vacuum with limited iteration and end-user feedback. As a result, changes to the software may take longer to develop. The waterfall model limits the flexibility and adaptability of the software, making it only potentially attractive to a homogenous user group with static design variables.

Agile Design Model

Agile software development promotes adaptive planning, evolutionary development and delivery, setting compartmentalized goals for an iterative approach, and encourages rapid and flexible response to change. It is a conceptual framework that promotes interactions throughout the development cycle.

The Agile design model is different from the waterfall model as it allows design feedback in the early stage of design (FIGURE 3.5). The software becomes more modular, allowing the software design to adapt to change.

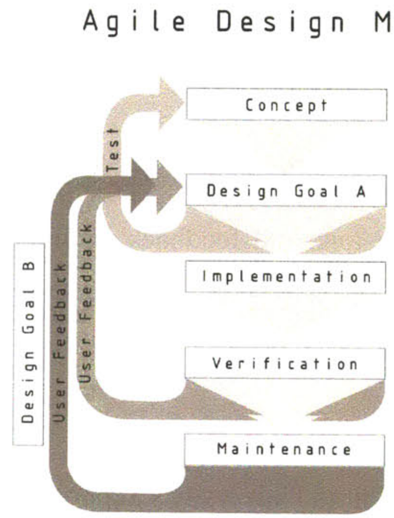


FIGURE 3.5: Agile design model

Concept: *Like any software development, there is an idea or a requirement, usually derived at the user level.*

Design Goal A: *Solving that immediate design problem to get user input and feedback before moving to the next stage of development.*

Test: *Have the end-user utilize the software to see if it meets the requirements of the user which may fall in multiple levels of feedback:*

"Is the button big enough?"
"Is the text visible?"
"Can you find the help menu easily?"

Feedback: *The end-user offers qualitative and quantitative input on the design that will inform the next phase of the design process.*

The agile software design model may encompass both end-user feedback on the design quality of the software, as well as computational optimization for speed at the end-user levels, all based on end-user feedback. In comparison, the waterfall model can be reduced to a solution that tests the reliability of computation for deriving optimal solutions divorced from end-user feedback. The waterfall model can be reduced to feedback based on computability and optimization. The waterfall model design works well for problems which are removed from the user, but require problem evaluations, such as processing time, and speed in order to validate the design quality of the software.

The design team had to develop a methodology so that their software development could be impacted by the decisions and feedback of the user group; therefore, they needed to rely on methodologies to evolve their design through end-user participation and feedback.

As Pelle Ehn, a Professor at Malmö University's School of Arts and Communication explains,

> *"Design-by-doing can be viewed both from the point of view of the users and the designers. This kind of design becomes a language-game in which the users learn about possibilities and constraints of new computer tools that may become part of their ordinary language-games. The designers become the teachers that teach the users how to participate in this particular language-game of design. However, to set up these kinds of language-games, the designers have to learn from the users."*[29]

Design Constraints: Designing Mobile Software for Fishing Communities

As previously noted, the main concerns in the fishing community are revenue generation from the daily catch, and the ability to have sufficient resources and supplies to fish. As a result, business transactions are based on the supply, demand, and monetary awards of sales of fish. In this study specific issues, such as lack of familiarity and limited use of technology, put constraints on the design and

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[29] Douglas Schuler, Aki Namioka, "Participatory design: principles and practices"

development of mobile phone technology for the target community. Most members in the community use mobile phones as part of their daily work; however, the use is limited to calls and sending SMS messages to colleagues. Most of the community members had limited college level education.[30] Most of the communities' academic experience consisted of either primary school level or high school level education.

Methodology Used by Design Team

The mFisheries software application was developed on a smartphone to be used in the fishing communities. A smartphone is a mobile phone with additional features available to the end-user to engage in the use of additional data options. These features include media players, digital cameras, Geographical Positioning System (GPS), WI-FI (Wireless Fidelity), and other "on-the-go" applications. A series of Google[31] Android-enabled[32] smartphones were used in the development and design of the mFisheries software suite. The selection of smartphones was based on the designers' preference, along with software availability for encoding new features and applications that would reside on the core Android operating system of the mobile phone.

The designers conducted comprehensive, quantitative and qualitative surveys in 51 communities throughout Trinidad. The surveys targeted users using traditional face-to-face means in the preliminary design stage. The designers then analyzed the outputs of the surveys to derive key challenges and to synthesize recommendations for solutions based solely on the empirical data. Key community members who had

[30] Survey conducted by UWI design team in 2010
[31] Internet and software company established in 1998
[32] A Linux-based based operating system deployed on smartphones

relationships with the local small-scale fisher folk were engaged as mentors and guardians for the designers' introduction to the small-scale fishing communities. The designers subsequently spent many months building relationships directly with small-scale fisher folk, and selecting individuals with whom to partner in the collaborative design and development process. Regular face to face meetings, both informal and formal, continued for several months, after which mSurvey was introduced as a means of feedback from field trial users.

3.3 Using mSurvey in the Design Process of Mobile Phone Software

mSurvey was used to assess a set of design variables and to assess the usefulness of the mobile applications while they were being developed. The usefulness criteria were applied to test the general hypothesis which was:

Key challenges to the development of the small scale fisheries sector can be overcome by using mobile technology for more efficient and effective communications.

Examples of tests to which this hypothesis was put include:

- Small scale fisherfolk can save time when they use user-centric, purpose-designed mobile applications to support their livelihood.
- Small scale fisherfolk can reduce waste when they use user-centric, purpose-designed mobile applications to support their livelihood.
- User-centric, purpose-designed mobile applications are perceived as being user-friendly and easier to use than general communications means, in supporting small scale fisheries' livelihoods.

- User-centric, purpose-designed mobile applications are perceived as being more convenient than general communications means, in supporting small scale fisheries' livelihoods.
- User-centric, purpose-designed mobile applications are perceived as facilitating greater personal security in the conduct of small scale fisheries' livelihood activities.

Enabling Participatory Design with Fishing Communities

The designers had to engage multiple fishing communities as they designed, in parallel. There was an intrinsic fishing community culture, in which those using the designs (mobile applications) were all fisher folk who spent most of their time out at sea at differing times, with the aim of finding their daily catch. As a result, there was an absence of the convenience of face-to-face interviews for feedback on how the designs might have impacted or were impacting their lives, how the designs might fit their needs, or what would be necessary for the next design iteration.

Internet and personal computer penetration among the fishing communities are very low. However, if they were present, they were mainly available for younger family members (generation) to conduct their school requirements and fulfill their social relationships. The predicament reduced the possibility of getting feedback through more "traditional" means such as emails, online surveys, or videoconferencing. The technology was either not available or those using the technology were not the users with whom the designers needed to communicate.

The team found it was important to engage the end-users using mSurvey to offer feedback on the mobile devices used in the design study. This approach was two-fold: it got feedback from the end-users through mobile communication, and the feedback methodology engaged the users to use the mobile phones more, increasing the familiarity with the device and encourages the use of other applications.

The designers were challenged with the dispersed nature of the communities. The fishing communities resided on the outskirts of the island interfacing with the ocean, while the design team lived and worked inland (Port of Spain). The commute to each location would sometimes develop into a 3 hour journey, and 3-5 days of logistics, planning, and communication, in order to engage the end-users in face-to-face meeting and feedback discussion. The surveys were initiated in a total of 4 communities, located at each corner of the island, making it difficult to get quick feedback and, therefore, significantly reducing the agility of the design process.

3.4 Quantifying Design with Feedback from Communities Using mSurvey

The designers developed a few metrics which were used to quantify the feedback from the end-users. The metrics proved to be very useful to the designers, due to the remote design setting and the mode of communication used to get feedback. Iterative design tends to lend itself to the subjective nature of feedback and engagement, which become very qualitative. Conventionally, intimate interaction is sometimes necessary to develop a complete understanding of how the end-user engages with the design. However, the designers suspected that frequent reporting could also help. The interaction between the designer and the end-user in this setting is a bit limiting and non-traditional due to the physical distance. The designers were therefore tasked with developing an approach to derive qualitative information from quantitative feedback, or quantitative information from qualitative feedback. For instance, a quantitative reply to the question, "Is the button too small?" would have to be decoded into screen dimensions if the end-user responded "Yes".

mSurvey had its limitation and could only send and receive very short messages to and from the users. All messages, responses and questions had to be structured in less than 160 characters.[33] The 160 characters limited the feedback to multiple choice questions, "all that applies" questions, branching logic, and open ended questions. The limitation helped the designers define the questions they needed answered in a rigorous way, in order to get the most useful answers to help them develop an understanding of end-user patterns. The designers wanted the patterns to indicate and guide the iterative sequence of the designs.

Prior to the first introduction of mSurvey to the community in January 2010, the designers had the luxury of asking longer questions and had the ability to get a full length account from the end-users. mSurvey was a new way of evolving the qualitative approach in a way that would get input from the users at more frequent intervals, improving the agility of the design process.

To conduct face-to-face interviews, the team took frequent trips with substantial planning which included team members making calls to all users who participated in end-user testing of the mFisheries software development. The design team was responsible for facilitating forum events that would educate the fisher folk on how to use the mFisheries software and get feedback in the process.

[33] M. Milian, L.A. Times, "Why text messages are limited to 160 characters" (2009)

FIGURE 3.6: Fisher folk in Toco region

In January of 2010, the author took a trip to the different fishing communities with the design team (FIGURE 2.7). The planning described by the design team took a few months. The design team had to decide the correct week to make site visits, contact the fisher folk, arrange vehicles, and arrange an overnight stay at one of the locations. This process was the normal process conducted by the design team when field visits became a part of the design and development of the mFisheries software. The average timeline and process are defined below:

Calling fisher folk: 2 weeks
Transportation planning: 1 week
Arranging room and board: 1 week
Time at each location: 3 – 4 hours
Total trip: 2 days

FIGURE 3.7: Author in field with fisher folk

The planning time obstructs the agility of the design process and discourages the designers by reducing the frequency of visits. However, it is not confirmed that the design success increases with end-user feedback on field visits. Nevertheless, it might be impacted by improving the means to acquire the information needed without assumptions. When user-centric assumptions have to be made throughout the design process, they may not capture the perspective of the end-user, which might have adverse design effects, making the design inaccessible or not useful to the end-user. The goal of the designers was to therefore remove the barrier by increasing the frequency of interaction between designers and end-users, and increasing information as input into the design process.

3.5 mSurvey in Trinidad and Tobago

mSurvey was simultaneously being tested for stability when accepting end-user feedback. At times, there were a few technical difficulties in getting information from the fisher folk. However, this case study describes the intent of the designers to acquire the information, and the ways in which they utilized the technology to be part of the design and development of the mFisheries mobile suite.

The design team was interested in using mSurvey to assess their design approach through 3 categories: 1) The activity of the fisher folk, i.e. did they fish, sell, buy, or process fish; 2) the need to know the prices of fish in the market; and 3) the familiarity with safety and location information.

There were a total of 25 questions divided into 2 questionnaires, asked during this case study. One questionnaire, deployed earlier in the case study, was a general assessment of the fishing community. The second questionnaire, called the "Usability" questionnaire, focused on how the fishing community used the phones and the mFisheries software developed by the design team.

A series of questions asked by the designers to the users is discussed below. The questions exemplify the importance of a participatory design approach in the design process between the designers and the users. The initial question of participation was assessing the population and their roles in the fishing community. A question such as the following was important to design their applications based on a majority pool.

Which of the following do you do?

1. *Catch fish*
2. *Sell fish*
3. *Buy fish*
4. *Process fish*

(A complete list of questions and graphs can be found in the Appendix)

The designers were tasked with coming up with a few survey instruments (questions) they could use to engage the end-users. The survey instruments, as defined by the design team, were a series of questions that included both single input from the end-user and, at times, long sentence feedback. The survey instruments were first written as text documents in the following format, before mSurvey's interface was developed:

Q. How many days a week do you fish?
0 - 2
2 - 4
4 - 6
7 days

Q. Do you sell fish in Port of Spain?
yes
no
(see Appendix for complete list of questions)

The text document was saved as "FILENAME".txt and uploaded to mSurvey for activation and deployment. The software would parse the uploaded document into the format in order to structure the questions as SMS survey questions. The Q# stands for the question to be asked, followed by the possible choices to be selected by the user. As in the example, question 1 would be formatted on the mobile device such that the end-user would read,

Q1. How many days a week do you fish?

1. *0 -2*
2. *2 -4*
3. *4 -6*
4. *7 days*

The end-user would then reply on their mobile phone with the correct answer. If the end-user went fishing 3 times a week, the end-user would reply with the selection 2 as a text. In some instances, the designers would then ask the users to answer a question with free input, in order to get a subjective review of the design. Although the users were given the luxury of answering a question more openly than when constrained by a notation, they were constrained by the 160 character limit of mSurvey. Most of the questions asked by the designers took the form of selecting a choice, which later developed into advanced logic, used to guide the end-user down a decision tree based on their selection of different answers.

FIGURE 3.8: User with Motorola Defy phone

The phones used in the design of the mobile applications were also new to the designers. It was noted, by one of the designers, the type of phone distributed was a Motorola[34] Defy (FIGURE 3.8) with the Android operating system. These were new to Trinidad and Tobago. In addition to the utilization of the applications on the phones, the designers were also interested in the design of the phone itself. The designers had no influence on the design of the physical phones, but were curious to know if this might in some way influence the user's experience and ultimately impact the design of the mFisheries software. The designers developed a series of questions, specifically targeted to the physical nature of the mobile phone, to get feedback from the end-users. These questions included the following:

[34] Motorola Inc. telecommunication company

Q. What do you think about the phone's weight?

Too heavy

Too light

Just right

Q. How easy is it to use the phone?

Very easy

Easy

Somewhat difficult

Very difficult

Q. How is the phone's battery life?

Very short

Short

Satisfactory

Long

(A complete set of questions is outlined in the Appendix.)

The questions were uploaded to mSurvey and reformatted as SMS questions to be administered to the end-users. The designers used two methods to engage the end-users in the SMS surveys. These two methods were:

1. A traditional forum (focus group) setting, where designers would engage about 20 – 30 end-users at the same time in a room similar to a lecture hall (FIGURE 3.9). The designers presented the agenda of the meeting as a group and would have the end-users participate in the survey during this time using their mobile phones. A group setting increased the end-user input due to the presence of the designers who could assist the users, which expedited the process of feedback by shrinking the feedback time to a fraction of the time of conventional face-to-face interviews.

FIGURE 3.9: Group meeting of fisher folk and mFisheries team

2. Calling the end-users and reminding them to take part in the survey. The users sent an SMS with the name of the survey as a code to a telephone number provided, to the mSurvey software. The survey code would then trigger the survey the designers wanted the end-users to take.

3.6 mSurvey: User Experience

mSurvey had to be intuitive in order to promote the level of engagement needed. The emphasis was placed on making the form of communication as intuitive as possible, so as to not distract the end-users from the main objectives of the designers, to get feedback on their software applications. It was apparent that the method was beneficial; it engaged the end-users in the utilization of the mobile device as part of the feedback about the device. The designers created survey codes for the end-users. Some examples of codes were FISH, USABILITY, and MAHI for ease of remembering. When the survey code is sent via SMS by the end-user, it is routed to mSurvey through the telecommunication network. mSurvey sends the first question of the survey which is routed back to the participant. This routing mechanism creates a communication loop between the respondent and mSurvey, until all questions and inputs are received and partitioned as feedback through mSurvey – at which point, the survey will be closed to the end-user. Each response is aggregated with other responses received from all the end-users who participated in giving feedback. Since the information received was in real-time, the designers could access the feedback on a web portal, which they were able to use in the subsequent stages of design.

mSurvey was used as an intervention and means of exploring the feasibility to receive feedback on the design goals of the UWI team. As the Trinidad and Tobago case study was one of the first case studies to use mSurvey to engage communities remotely to get design feedback, it was equally important to get feedback on the technology and some of the complications the designers experienced, in order to improve the methodology of mSurvey. The mode of engaging users in a remote design context was novel to all parties involved and, therefore, needed to also be iterated for improved success. The author interviewed a few designers from the UWI team to get their feedback on the mode of communication used with their user group.

3.7 Interview with Software Designers

After multiple interactions, technical failures and end-user interaction with the SMS survey, the author consulted the designers for feedback on the process. The aim of the interview was to gauge their perception of designing software without end-user feedback, and their perception of the need for participatory design in the agile approach. The interview also served the purpose for getting feedback on mSurvey itself, how necessary it is, and how it can be improved to be inserted into the remote design process. Below are a set of questions conducted in the interview with three designers from the UWI team.

As described in the context section of this case study, there was a social class distinction between the fishing community and the designers. As a result, there were assumptions and preconceived notions which may have drastically affected the design if the end-users were not engaged at early stages in the design process. The author saw evidence of this when the designers were asked the following question.

Author: Kindly describe your initial assumptions before designing with the community

Designer: 1) Careless - Inability to keep the phone safe at all times and being careful about the whereabouts of the expensive mobile device.

2) Older persons as opposed to younger ones - I thought that the fishermen of our country were mostly older folks and, hence, lead to the assumption of the steep learning curve to learn how to use the phone.

3) Lack of Foresight - I also thought that they might not see the true benefit of what we are proposing to them... they might just see it as 'bling bling'.

4) Illiterate: They might not grasp the technical aspects of the application.

Designer 2: Fishermen easily spend money, and like flashy material things. The phone must be attractive to the fishermen.

Designer 3: Illiterate (functionally, with the use of English and Mathematics, and technically, with the use of the phone and its features)

The designers assumed many things about the community. The assumptions ranged from illiteracy among the community members to the community members not seeing value in their design process. These assumptions made it necessary for the designers to include the community early in the stage of the design, in order to mitigate any preconceived notions that would blanket the design. As a follow up, the author asked the designers what assumptions were removed and what value the participation brought to their design process. The answers offered insight and emphasized the importance for designers to engage the end-users in the process to remove any pre-judgment that would affect the design results and, therefore, significantly reduce utilization.

Author: How did information from the community participation remove or reinforce those assumptions?

Designer 1: 1) Seeing them keeping the phone safe and in good condition (for the most part) removed the 1st one.

2) Seeing younger persons in the business removed the second one.

3) Seeing the younger ones take the real purpose of the application and the phone for granted reinforced my third point.

4) The 4th was removed also, but still lingered for two of the participants.

Designer 2: Close interaction reinforced this point. Speaking to the fisher-folk during (sic) regular allowed us to be aware of this. The low usage of application by some fisher-folk, coupled with their unwillingness to part with the phone also lends support to this opinion.

Designer 3: Some of the younger participants were very knowledgeable in the use of the mobile phone features or were very quick to learn.

The designer's perceptions changed once immersed in the community. Some of the assumptions were reinforced while others were removed. Despite the non-conventional design approach the designers took to engage their community of users, it was important to see how feedback affected the process.

3.8 Analysis: Results from Using mSurvey within fishing Communities

Although the use of mSurvey implies how information is important in designing for remote fishing communities, it is equally important for the designers to develop an ethnographic approach, while utilizing the feedback facilitated through the utilization of mSurvey. Greater participation helps designers in gaining insight to improve the rate of iteration if the communities are highly segmented. mSurvey improved the relationship with the fishing communities and the designers by increasing the dialogue and feedback on multiple iterations in the design development. The agile software model was important throughout the design and development of the mFisheries software suite, as the designers wanted their design process to remain flexible. Although the designers were all from Trinidad, they were somewhat removed from the community dynamics, which relied on frequent engagement. The frequent engagement also required frequent changes and adjustments, which supported the choice of agility within the design process.

mSurvey contributed as a way for the designers to collect quantitative information from precise questions asked the communities. The designers were more cognizant of the questions they wanted to ask and tailored the questions to get the best feedback possible. The 160 character limitation of communication between the designers and the fishing communities proved to be helpful when asking concise questions. The character limit also proved helpful by forcing the designers to iterate questions, in order to reduce the ambiguity between the questions and the feedback from the users.

Types of questions and answers

Open-ended answers were more difficult to gauge because the answers would require an additional layer of software, which was not present at the time of this case study. The additional software would be used to detect keywords that would link the feedback from the end-users through relationships and associations, to be used in the design process.

As mSurvey was being developed, the author, as well as, the designers saw the importance for branching questions. Branching questions would lead the end-user, based on their answer, to multiple tiers of questions. However, branching questions were not utilized in this case study. The software architecture for branching questions on mSurvey was developed in subsequent iterations of the mSurvey software development. Branching questions are very helpful in determining the direction of a response and would get refined feedback from the fishing communities. An example of the use of branching questions would be to ask questions such as:

Would you like to have a compass on your application?

Yes

[branching]

Tell us how you would use your compass:

[open-ended question]

No

[Next question]

Asking an open-ended question, like the one above, would give the designer insight into why the compass would be important to the user. Having collected all feedback from the end-users on their verbal expressions for wanting a compass, the designers could search for patterns in the answers in order to quantify how to develop a design specification from the aggregated feedback.

The participation of the end-users played a significant role, due to their remote locations and agility of the software design, despite the cultural similarities between designers and end-users. Although end-users may have shared very important and obvious similarities, end-user preferences, aesthetics, and other qualitative measurements were necessary in the design process to transfer the design for independent utilization by the end-users. In the case study developed between the

UWI designers and the fishing communities, the designers had to engage the users early in the design process if successful results were desired.

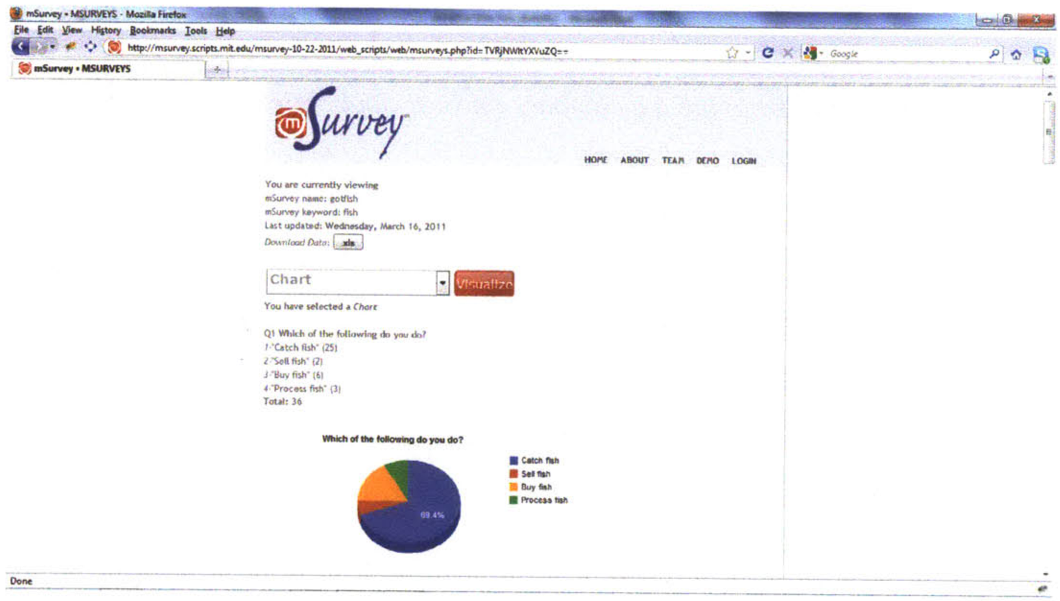

FIGURE 3.10: Dashboard view of data designers observed in real-time

The team members were able to view results on a web interface in their lab (FIGURE 3.10). The results were automatically graphed in real-time to improve the agility in the design process. Some of the results showed that 69% (FIGURE 3.11) of the communities catch fish.

Q1 Which of the following do you do?
1-"Catch fish" (25)
2-"Sell fish" (2)
3-"Buy fish" (6)
4-"Process fish" (3)
Total: 36

FIGURE 3.11: Results showing 69% of the fisher folk catch fish

It was important for the designers to determine what the percentage meant; i.e. if the end-users who replied spent most of their time catching fish and selling it in bulk, or if they caught fish for their own consumption. If the latter, the designers were forced to gauge the significance of the application to this population if the goal of the designers was to increase the communication channel between buyers and sellers to improve the fishing economy. One key driver in support of the mFisheries software application was that 80% of the community asked was interested in finding out the daily price of fish in the main market of Port of Spain. This finding supported their "Got Fish, Need Fish" portion of their application, reinforcing the need to have dynamic prices in the market, dictated by the buying and selling relationship between fish buyers and sellers. As a result, 78% supported the need to advertise fish to sell or buy. The result of the need to advertise fish to sell and buy was necessary in confirming the designers' assumptions in designing an application that would be useful for key stakeholders in the fishing community.

The designers were interested in adding additional value to the mFisheries application with components such as GPS, compass, first aid solutions, and "cool tips", but needed to assess if these features were important or even desired by the fishing communities.

Although the quality and type of questions were important to ask the end-users, it was noted by the designers that the analysis of the answers was equally important. mSurvey offered basic partitioning of the data in real-time to illustrate and display aggregate information received from the end-users. However, the designers were interested in compartmentalizing the feedback if necessary. The designers wanted the ability to look at each response individually and compare the answers, based on end-users. The designers stated that this would help them to hone in on similar patterns and behavior which would enable them to make better design decisions moving forward. Although the information was collectively important, the ability to understand each end-user pattern was just as important.

Using mSurvey within the fishing communities revealed many significant advantages of remote communication between the design team and the end-users. This case study revealed that mSurvey can be applied in each phase of the agile software model chosen by the design team (FIGURE 3.12). This case study also revealed necessary improvements, which were subsequently made with the mSurvey software. Improvements, such as branching questions to increase the resolution of feedback, were developed in subsequent versions of mSurvey. Network coverage was a key observation made in this case study. The community was mainly fisher folk which would result in the end-users physically being in locations of significant distances from telecommunication towers, while at sea. Unlike other modes of communication, mSurvey offered end-users the ability to pause and save answers, while the end-user was taking the survey in the event of network failure (distance from tower), battery failure, or distraction with a phone call or other daily activities. The end-users were always given the opportunity to resume where they had left off in the questionnaire, or given time to think more constructively about their answers before replying. mSurvey would remember where the end-user was within a questionnaire (the end-user state) which offered a new way of interacting with the design and allowing the users to leisurely offer feedback.

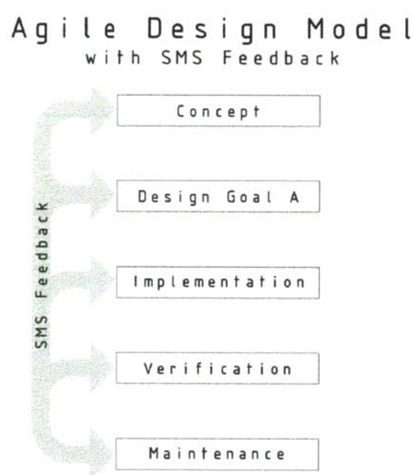

FIGURE 3.12: Agile design model with mSurvey feedback

The use of mSurvey in developing the mobile applications for the fishing communities offered the designers greater flexibility than they had without consistent feedback. mSurvey reduced the distances between the communities and the design team. mSurvey reduced face-to-face communication while increasing the frequency of end-user feedback (FIGURE 3.13). The increased communication between the design team and the communities offered higher frequency of information which offers the potential for higher rates of iterations (FIGURE 3.14).

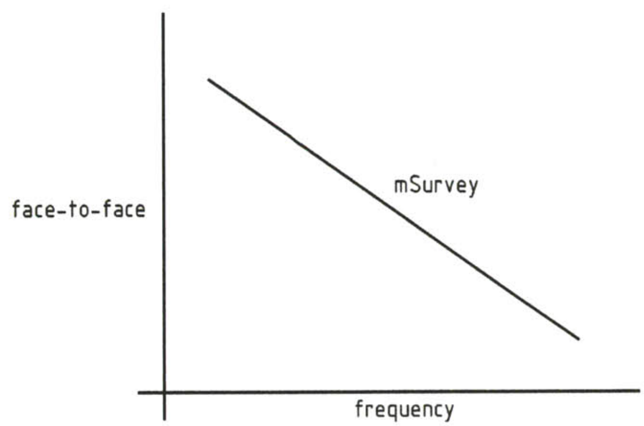

FIGURE 3.13: Frequency of feedback compared with face-to-face

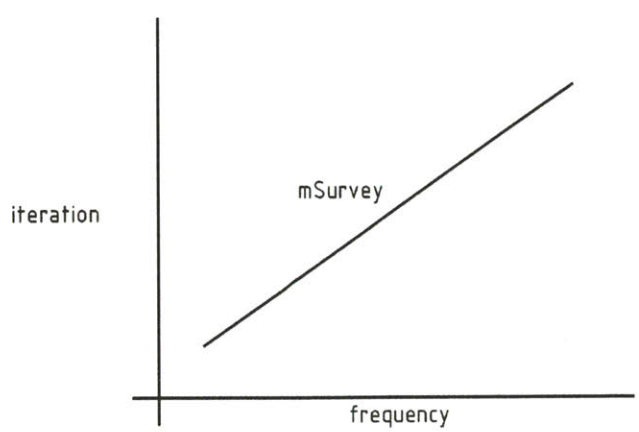

FIGURE 3.14: Frequency of feedback improves iteration

3.9 Contributions

The mFisheries case study was structured to understand the need for technological intervention in order to increase end-user feedback for greater design and technology uptake in Trinidad. The use of mSurvey emphasized how frequent snippets of information helped in developing a deeper relationship and understanding of the fishing community for better mobile design solutions.

CHAPTER 4

Designing an Eco-San Facility for Urban Informal Settlements: A Kenya Case Study

The following case study illustrates how mSurvey was used in Kenya to engage a community who resided in low-income areas in Kenya. mSurvey was used to get sensitive feedback from the community in the design and development process of a localized sanitation system.

The urban population is expected to double between 2000 and 2030 in developing countries.[35] The significant population growth makes it difficult to maintain infrastructure, and to construct housing designs at the expeditious rate needed by the communities in these regions. As a result, the demand grows much quicker than the availability of sustainable infrastructure.

A major problem with population growth and the lack of infrastructure is the lack of proper sanitation facilities. Most sanitation facilities are poorly designed and provide temporary relief for a pervasively growing population. Most often, solutions are concocted remotely, by designers and engineers who are not local to the region. Solutions are expeditiously transferred into communities after limited iteration or interaction with these communities by the designers, with limited design feedback to sustain the expanding and volatile population growth.

Specifically, sanitation is a pervasive problem in parts of Kenya, especially in the informal settlements in some urban regions (FIGURE 4.0). The problem is persistent, due to the lack of well-designed infrastructure and utilized models that integrate

[35] United Nations Population Fund, "Unleashing the Potential of Urban Growth" (2007)

seamlessly within the community for a sense of permanence[36] and cultural sustainability. The presence of improper design solutions fail to engage the community as part of the design process, which in turn fail to address the actual need at the community level.

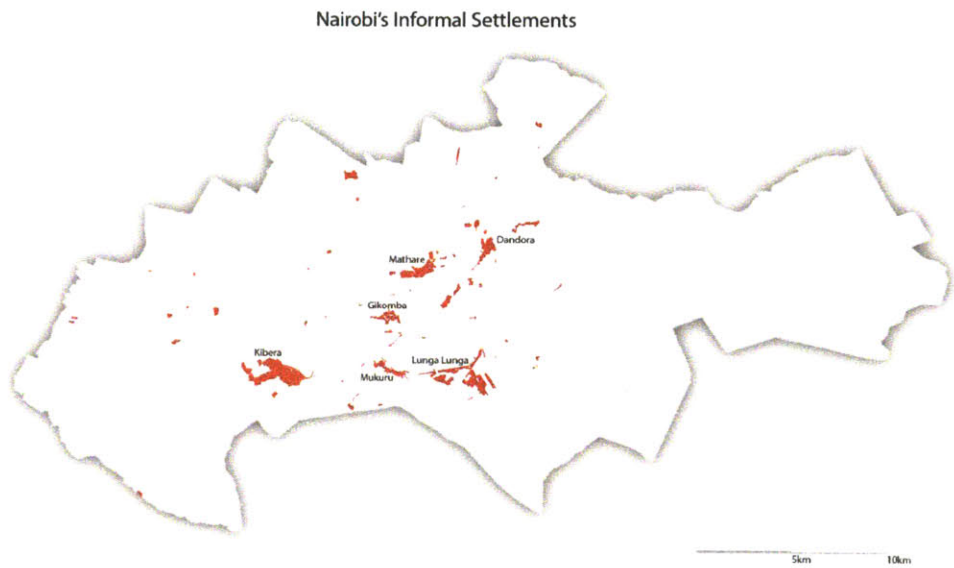

FIGURE 4.0: Informal settlements in Nairobi

This case study examines the design and development strategy of sanitation facilities by a team of MIT architects, engineers, industrial designers, and MBA candidates. The case study describes how the team engaged a Kenyan community in developing a well-received sanitation facility into their community. The study describes the team's methodology which included the utilization of mSurvey as a mode of communication and engagement with the community. The use of mSurvey became specifically necessary in addressing the personal and sensitive feedback that was needed to iterate and revise the design of the sanitation facilities.

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[36] Feedback from Kibera residents in June 2010

4.0 Africa: Nairobi, Kenya

With a total of 54 countries, Africa has a vast array of cultures, languages, heritages, and many centuries of history. The case study took place in the Republic of Kenya. Kenya is located in East Africa surrounded by the countries of South Sudan, Uganda, Tanzania, Somalia, and Ethiopia (FIGURE 4.1). Kenya has a growing population of 41 million, with a diverse culture from tribal influences. The design intervention by the design team took place in Nairobi, the capital of Kenya, which had a population of 3 million at the time of case study. Nairobi is considered the most populous city in East Africa, and a central hub where many rural communities migrate to earn a better wage.[37] As a result, the migrant population moves to urban communities, to live alongside a collection of other communities from different rural regions. The constant migration of many different communities exemplifies the potential volatility of infrastructure and the influence of different perspectives from cultures of diverse sets of rural communities. Although Kenya's language is Kiswahili, Kenya has a derivation of dialects attributed to the different regions of migration. The languages fall under two major groups, with a total of over 10 derivations. However, English is widely spoken in Kenya.

[37] Kinuthia Macharia, Migration in Kenya and Its Impact on the Labor Market, Conference on African migration in Comparative Perspective, Johannesburg, South Africa (2003)

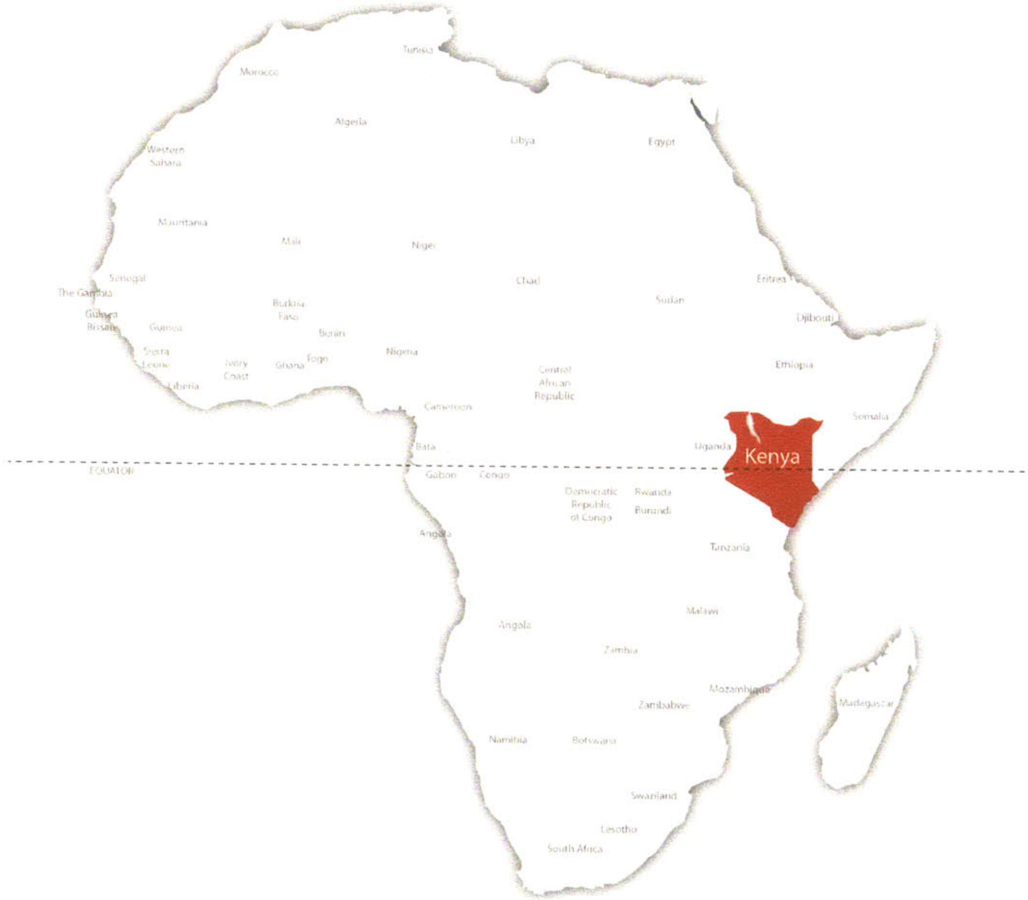

FIGURE 4.1: Location of Kenya in Africa

Kenya Economy

At the time of this case study, Kenya had an unemployment rate of 40% (2008) and ranked 184 in comparison with other countries' global economies.[38] Kenya's labor force is mainly within the agricultural sector, but this is changing to include technological innovation, due to an increased concentration on new accelerated

[38] Central Intelligence Agency, World Fact Book

development strategies and the presence of telecommunication infrastructure. Kenya is well-known for the production of coffee and tea, and imports a significant amount of other products present in the market. Due to the high unemployment and lack of opportunities, the economy grows very slowly, while the population grows rapidly. This growth causes an imbalance in the amount of resources. Kenya relies on financial reserves to provide proper housing and infrastructure for residents living in urban informal settlements.

4.1 Design in informal Settlements

The designers for this case study were architects, mechanical engineers, industrial designers, and MBA candidates from the Massachusetts Institute of Technology (MIT). The members of the team were from different countries, and states in the United States, all with different levels of exposure and experiences; therefore they had different understanding of the context of developing countries. The design commenced in June 2010 and is still ongoing. The design team was tasked with developing sustainable Eco-San (sanitation facilities) to be integrated and managed by the communities in which the facilities were developed. The design team focused on developing a sanitation system that would not only be a functioning part of the community, but also a way to improve the disposal and reuse of waste for bioenergy. The team was interested in developing a business model using local methods of construction, as well as training for local maintenance. The ultimate goal of the designers was to improve sanitation access within the communities which would therefore reduce chronic health problems.

The community members were from Kibera, Kenya. Kibera is known to be one of Kenya's most widely studied "slums" or informal settlements. Kibera is located in the center of Nairobi and has a population of over 250,000 residents. Although located in the heart of Nairobi, the Kibera community is removed from interfacing with the Central Business District (CBD) and operates somewhat independently (FIGURE 4.2). Most community members in Kibera do not have adequate sanitation in their homes, and have to walk significant distances to utilize these facilities.

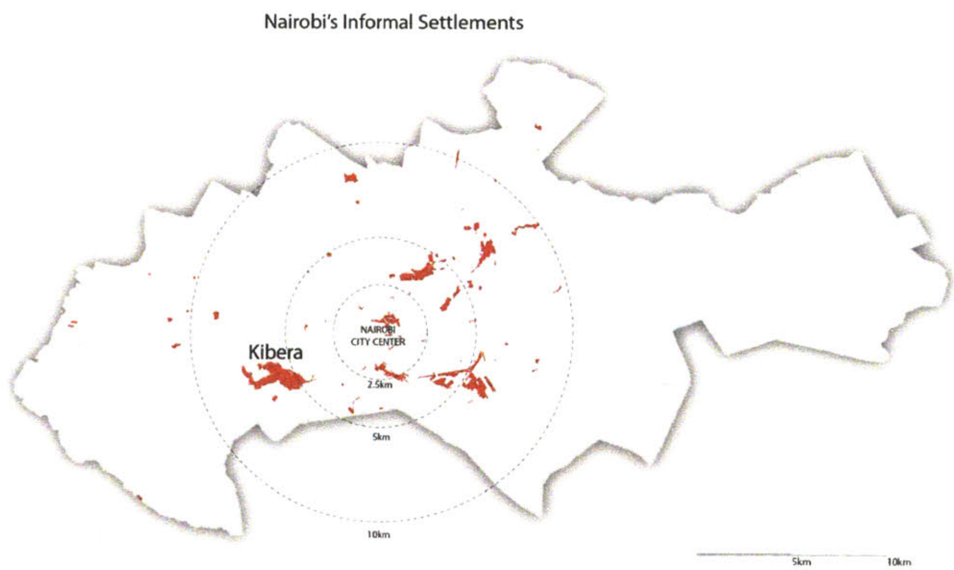

FIGURE 4.2: Distance between Kibera and CBD

In addition to improving the design of the current sanitation systems in the community, the team was tasked with bringing completely new sanitation facilities to communities where none existed. The goal of the designers was to design a system that would easily scale within the community of Kibera and to other communities across Nairobi. The team not only had to immerse themselves in the culture and understand the community dynamics, but they also had to understand the availability of construction resources within and outside the community.

4.2 Team dynamics: From Engineers and Architects to Community

There is limited infrastructure in Kibera that connects homes to municipal services such as plumbing and electricity (FIGURE 4.3). There were no sewer lines or plumbing, things one would find in a fully-planned and developed city.

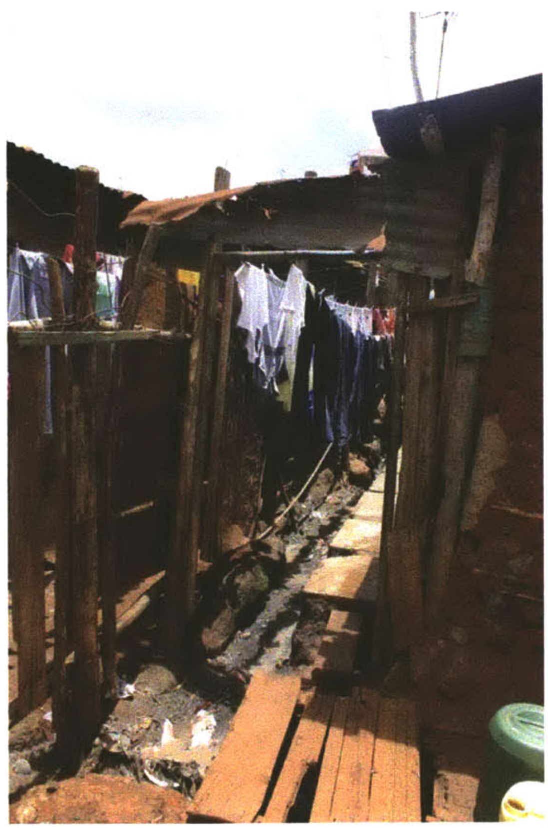

FIGURE 4.3: Typical drainage system within some communities in Kibera

The MIT team, spanning from trained designers to MBAs, all played an active role in developing the design solution. The intent was to design a self-contained sanitation unit that would require a maintenance team to extract the waste and deliver it to a processing plant for energy processing. The system had to be a complete operational solution, from community utilization to maintenance; therefore, the design team had to actively think of all the necessary variables.

Due to the nature of the case study, the questions investigated were as follows:

- How do designers engage the community in the design process of sanitation units?
- What kind of information is necessary to develop design ideas that correlate with the community's needs and desires?
- How do the community and designers share information about the design?
- How does the community offer feedback about the design, i.e. verbal, written, or visual cues?
- How do the designers engage the community locally and remotely? Is there a difference?
- What kinds of technologies can be (were) used in the community engagement process to develop more sustainable, collaborative solutions?
- What kind of information can be used in the design process and what are the questions that can be asked to get the information needed?
- How does technology aid the process of real-time information so that is it may be useful throughout the design?

The designers wanted to create sustainable designs for the community of Kibera, therefore, they needed to understand cultural dynamics in order to make design decisions and ensure their solution are successful. The designers had to engage the community members as active design critics at every stage of the design process. The community members were generally self-taught, do-it-yourself 'designers' (FIGURE 4.4) as evidenced by the nature of the physical structures within the communities – the physical structures of the community were often built from a juxtaposition of scrap material used to make living quarters.

FIGURE 4.4: Do It Yourself (DIY) construction in Dandora, Kenya (2010)

The physical and external aesthetics of the structures designed and constructed by the community were not a significant concern, due to the fundamental need to have a place to live rather than the time to plan and design. However, significant time was spent on the personalization/customization of the interior and ornamental aesthetics (FIGURE 4.5).

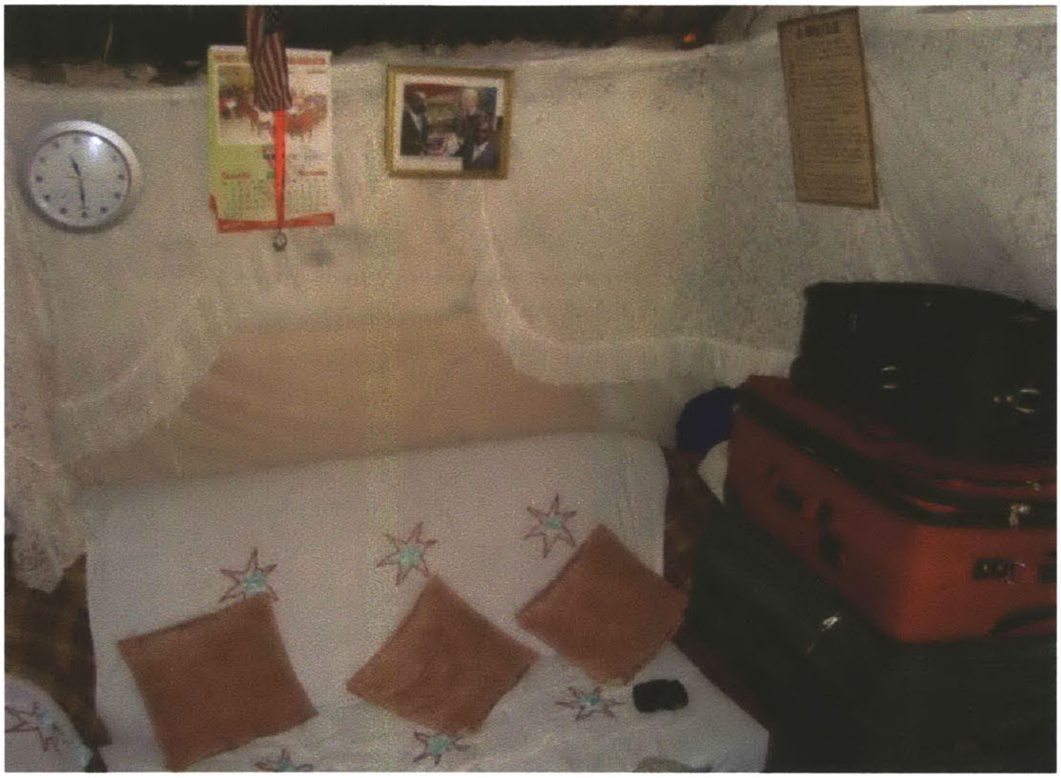

FIGURE 4.5: The interior of the home of a Kibera resident (10' x 12' in size)

This was evident when a community member inquired about the meaning of design in a survey conducted in July 2010 using mSurvey (FIGURE 4.6) (see Appendix for full survey results).

Q14 Would you be interested in designing your own house?
1-"Yes" (207)
2-"No" (9)
3-"Maybe" (10)
Total: 226

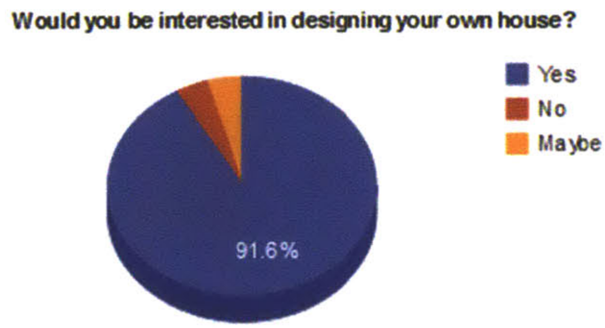

FIGURE 4.6: Over 90% who were interested in designing their house from 226 Kibera residents

Although most of the community members opted for the opportunity to design their own homes, many did not give it much thought or had the opportunity to be active designers. The engagement between the community members and designers was, therefore, necessary for the community members to acclimate to the design process. This acclimation provided community members the comfort and freedom of offering feedback on design variations or design variability that would aid the design.

4.3 CAD/CAM: Using Computer Aided Design and Manufacturing in Kenya

Computer Aided Design and Computer Aided Manufacturing (CAD/CAM) allow designers and engineers to produce, manipulate, and create designs for construction as digital files. CAM which includes Computer Numerically Controlled (CNC) technologies have been a part of engineering disciplines since the early 1940s,[39,40] and has been recently adapted to the field of architecture. CAM includes tools such as lasercutters, milling machines, 3D printers, and stereolithographic devices. The devices accept geometrical information as numerical data, for the design object to be manufactured.

Before the adaptation of 3D software for use as part of the design process, architectural design was a profession driven by physical models for the evaluation of designs as desktop models for the designer and the end-user. In past practices, designers created hand-made models as representations of the design intent and the implication of the potential steps for creating the life-size product.[41] The models were usually made from material that had been cut and manipulated by hand to match the paper draft of the design. After the slow migration of digital methods, such as CAD tools, designers were able to create design files that represented the intent of their concepts on a computer in digital format. Although the digital information was in the form of sophisticated numerical data, implying the use of machinery for production, the actual materialization[42] of the design was underdeveloped due to the significant investiture in visual representation, rather than fabrication and production processes.

Presently, there has been a pervasive presence of CAD/CAM methodologies throughout design and development stages. In recent practices, with the high use of

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[39] Ross D.T., (1978) Origins of the APT Language for Automatically Programmed Tools, ACM SIGPLAN Notices, Vol. 13, No. 8, August 1978

[40] Oberg et al. (2000) 26th Edition Machinery's Handbook, Industrial Press Inc. New York

[41] Cuff D., (1992) Architecture: The Story of Practice, MIT Press

[42] Sass L. and Oxman Rivka (2006) "Materializing Design" *Design Studies*, Vol. 27 No. 3 pp. 325 – 355

3D software and the introduction of CAM tools, designers are curious about using CNC technologies for the production of representational models, as well as physically habitable spaces, as seen in the design and construction of the Lord's Media Center.[43] Designers create designs using 3D software as non-conventional approaches, compared with past paper methods. However, the digital information suffers because of the limited approaches for materializing the shapes as life-size products.

Using 3D CAD software, such as Rhinoceros and Computer Numerical Controlled (CNC) tools like ShopBot, the designers were interested in harnessing these systems in their design process to be transferred to local technicians as part of the solution. CAD/CAM systems were important due to the precision of the physical construction they provide from digital information (FIGURE 4.7).

The architects, industrial designers and mechanical engineers on the team were tasked with designing a methodology for constructing the sanitation facilities expeditiously using CAD/CAM systems for the purpose of scaling uniformly throughout the communities. Due to the unskilled labor force, limited carpentry, and formal modes of construction, the designers had to consider the absence of professional construction processes as variables in their design solutions, if the goal was to localize the manufacturing process.

[43] Future Systems, (2001) Unique Building: Lord's Media Center, Wiley-Academy

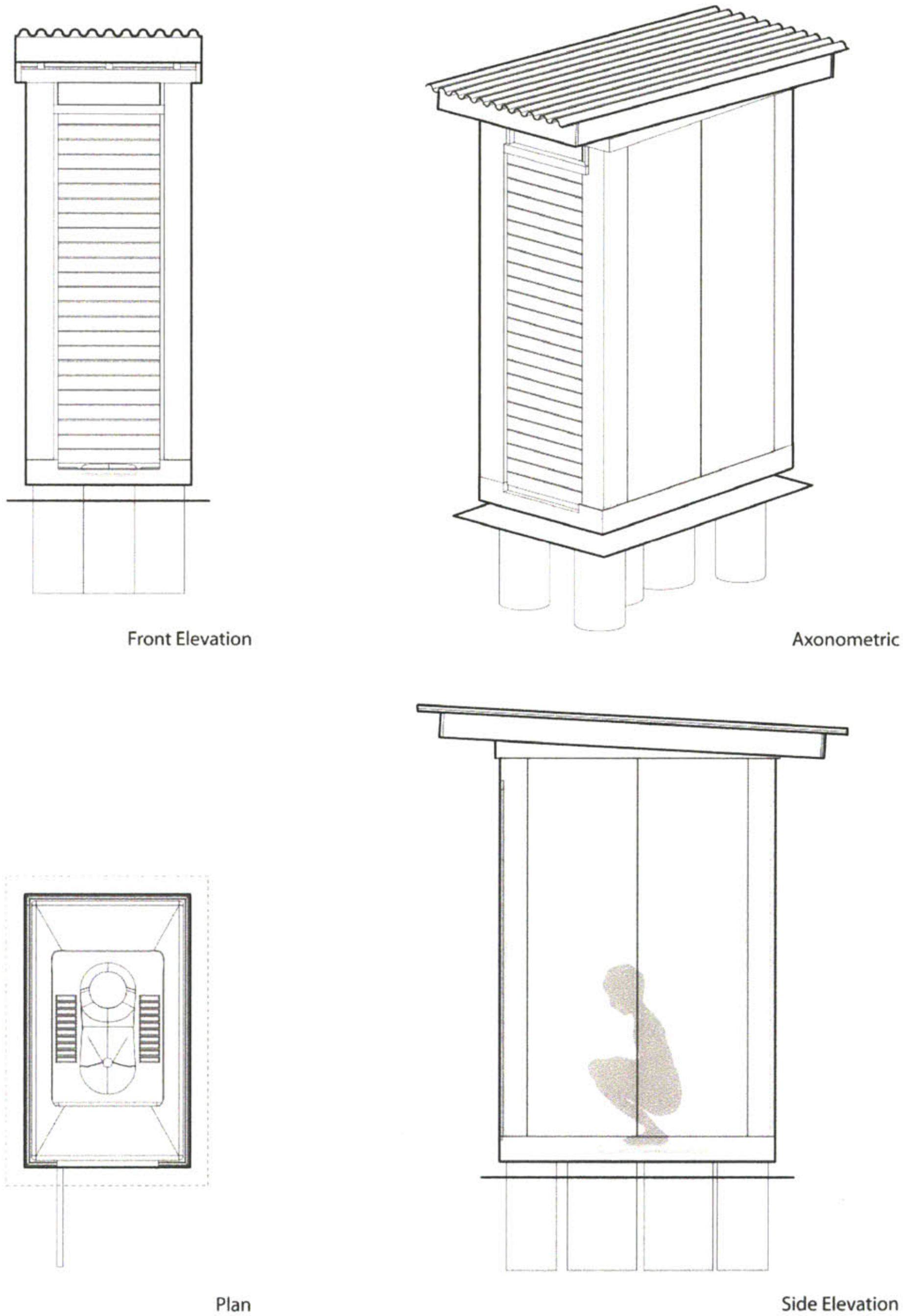

FIGURE 4.7: Digital files of design for manufacture and design feedback

The presence of CAD/CAM tools and the flexibility for manufacturing multiple design outputs allow the designers to work within the cultural context, disregard of the design feedback from the diverse set of community members with whom the designers would interact. It encouraged flexibility in the design, due to the ease of manipulation of digital files. CAD/CAM methodology enables the sharing of information (FIGURE 1.2), remote access of files and data via email or Skype, and the flexibility of deriving changes quickly based on end-user feedback. The methodology allowed the designers to conduct tests using desktop models manufactured using lasercutters, and usher the design through the stages of scaling for testing the structural integrity of the designs by using large-scale milling devices.[44] Technologies such as CAD/CAM forced the designers to be closely involved in rationalizing the form for life-size construction that mapped to the experimentation of the designs at desk-top size.

4.4 Design with Constraints: The Eco-San Facility

The design team's goal was to design an Eco-San facility using low-cost and water-free toilets. The system had to be constructed using precast concrete panels that were manufactured using CAD/CAM technologies. The design had to be culturally sustainable by the team's definition:

"Meeting the needs of the present without compromising the ability of future generations to meet their own needs," as paraphrased from the World Commission on Environment and Development for the United Nations General Assembly in 1987."

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[44] Botha, M. and Sass, L. Instant House (2006) Design and digital fabrication of housing for developing environments, CAADRIA 2006 Kumamoto (Japan) March 30th - April 2, 209-216

At each design stage, each design variable had to be assessed to confirm that the team was on the right path to a successful design solution. The designers wanted to engage the community in a participatory design activity, in order to receive end-user feedback throughout the entire design process. The community members did not have experience with assessing design variables nor did they have the opportunity to assume the position of being a client or an active end-user of a designed product.

The designers traveled from Boston, Massachusetts to Kenya in July 2010. Their main goal was to investigate what the community needed and how their designs would relate to the feedback from the community. Two of the designers were architects and focused on the design process with the use of CAD/CAM; two were MBAs and focused on the business and maintenance of the facilities; one was a mechanical engineer who focused on the utilization and functionality of the facilities; and the last was an industrial designer who was concerned with the ergonomics and aesthetics.

The team had a few variables they needed to assess, which included size of units, types of materials they would use to construct the units, how the community would use a toilet or sanitation facility, the availability of labor, the cost of each unit for scaling throughout the community, and adaptability for sustainability.

4.5 Enhancing Community Research and Outreach with mSurvey

The author worked closely with the team in developing a series of questions that would be asked to the Kibera community. The questions included queries about cost of living, income, distances from their homes to the nearest sanitation facility, their personal feelings towards talking about sanitation, and the effects of sanitation on their health. Sanitation can be a very sensitive issue to discuss regardless of gender. The team was especially concerned with the women of the community, due to safety and hygiene. The sensitive nature of discussing sanitation made it difficult to ask questions to the community through conventional face-to-face interviews for direct answers to influence the design direction of the end result. To overcome the lack of information and the need for direct and honest feedback, the team utilized mSurvey for communicating with the community members. mSurvey allowed the team to ask sensitive questions and receive direct feedback. The community members felt a sense of anonymity in offering feedback, which is discussed later in this case study.

The designers developed the questionnaire jointly with community partners to ensure the questions were coherent to the community. The team developed 2 different questionnaires, with an average of 19 questions each. The questions included multiple choice and open-ended questions, for input from the community members. Although Kiswahili is the main language of Kenya, the Kibera community had a great reading and writing command of the English language, which made mSurvey useful to deploy and get feedback for design development. The designers compiled a series of questions (see below) to be uploaded to mSurvey, which formatted the questions accordingly, and deployed on mobile phones:

Q. Are you male or female?

Male

Female

Q. How old are you?

18 – 30

31 – 50

older than 50

Q. What is your occupation or income generator?

Stay at home

other (text other: 'your explanation')

Q. What is your education level?

Primary school

Secondary school

University degree

Community school certificate

other (text other: 'your explanation')

(See Appendix for full list of questions)

Each question was parsed individually from the text file developed by the designers, which was formatted such that each line which started with 'Q.' was the question, and each return carriage below the question were the choices to be selected by the community member.

After the questions were uploaded and tested on the designers' mobile phones, they conducted focus groups to get community feedback. The focus groups included a member of the community that acted as the community aid – who helped develop the questions with the team, approximately 25 community members, and the design team. The community aid was responsible for informing the community members about the intent of the designers. The community aid was responsible for verbally educating the community about the designers and their design intent within the community. The community members took part in answering questions on their mobile phones in the presence of the designers. The role of the designers and community aid was to assert that the community members understood the questions and were available to clarify any uncertainties.

4.6 Design Remotely without Community Feedback

The design team developed a few design iterations in their labs in the United States before their first site visit to Kibera, Kenya. The team's designs were based on assumptions made from information gathered using online resources and material from other areas of research that concentrated on statistical information.[45] The information gathered by the team was, however, an assessment of variables developed by other groups of researchers, which sometimes did not align with the key concerns of designing a sanitation facility, and key concerns such as the difference in perspectives between male and female community members. The

[45] http://data.worldbank.org/

information researched by the designers was general, with lack of design specifics, and did not reflect what a community member might say about the design of a sanitation facility. On the campus of MIT, the team held a few design charrettes to brainstorm and develop a few design variations (FIGURE 4.8).

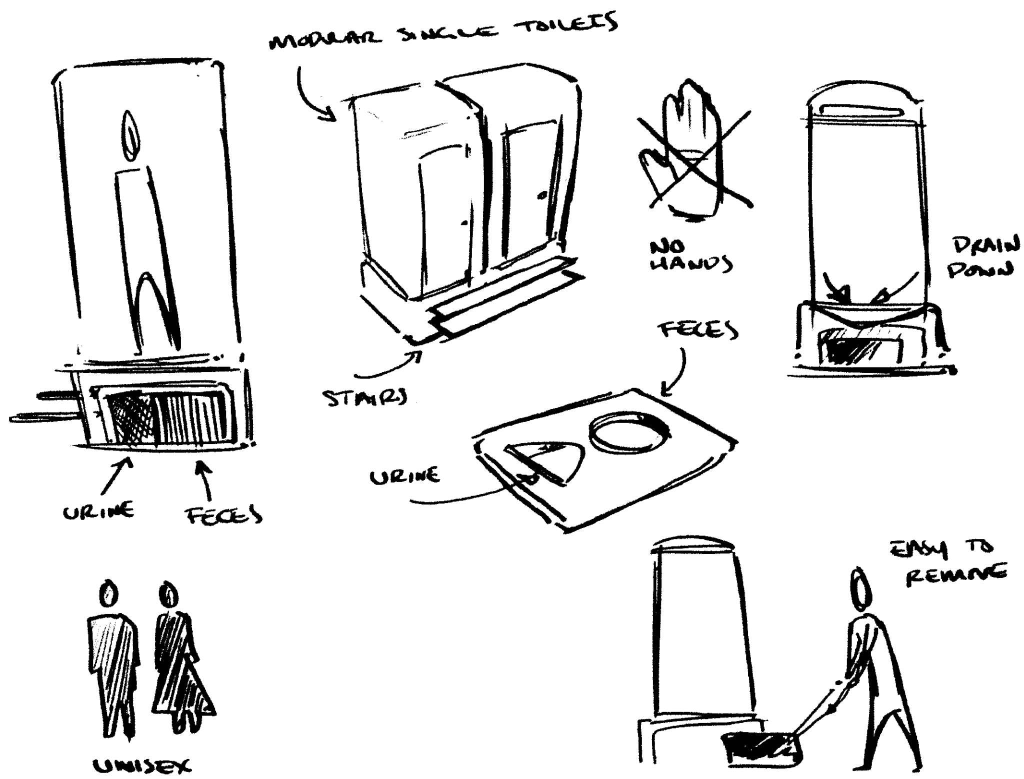


FIGURE 4.8: Design charrette of team (image provided by team)

The design charrettes included the research conducted away from the community and location, with major concentration on key variables that were not a function or reflection of designing sanitation facilities in the community. The key research concerns expressed by the designers were as follows:

Access to water:

How would access to water impact the design of a sanitation unit?

Sanitation units had to be cleaned with as minimum water as possible, therefore the design had to include filleted corners similar to that of a bathtub, to reduce the amount of water during cleaning.

Access to plumbing:

How would access to plumbing impact the design of a sanitation unit?

A self-containing system had to be built due to the lack of sewer access. The waste had to be contained in barrels to be removed, and had to be designed as part of the unit.

Cost of using a sanitation facility:

How would the cost of using the sanitation facility impact the utilization or the process of scaling?

In the Kibera community, members pay to utilize sanitation facilities. As a result, the designers had to know the costs to justify community members investing in a unit and maintaining it as a business.

Available materials and resources:

What kinds of materials are readily available and can be sourced locally for the use of CAM to construct the sanitation facilities? And, therefore, how would that impact the design?

The system had to be built with local material and resources in mind. The main material considered was ferrocement, which was locally used in construction practices.

Methodology of construction:

What kind of construction methodologies would have to be embedded in the design of the sanitation facilities?

The team wanted to assess if it was feasible to use CAD/CAM technologies coupled with the local craft to produce the sanitation units. If the designers were successful in doing so, this would imply that sustainability and scaling would be feasible.

Utilization (how many people can use it):

How many people would be able to use the sanitation facility (what is the utilization frequency)? How would this impact the design criteria?

The model presented by the designers required multiple units distributed in the community. The designers were required to know the utilization frequency of the units to gauge the potential scaling.

Sustainability:

Because all the members on the team were foreign to the region, they had to consider how the transfer of the methodology and the technology would impact the design solution. The design had to both appease the community and be designed to make the removal of waste easy and efficient

User-Friendly/Ergonomics

How would the design make the facilities more "welcoming" to the users?

The designers had to make sure that the mode of using the unit was one which the community would engage in. This included knowing how they used the current sanitation facilities, and developing a system that would consider health requirements and safety requirements.

Current designs (the alternative):

Why were current models not working and what design challenges did the team have to overcome to make their design successful? What did the team have to do differently?

The team had to assess why there was little being done about the sanitation problem in the community, and what they could do differently, given that the variables were assessed effectively.

4.7 Using mSurvey in Informal Communities: Kibera, Kenya

The barrier of entry into the community was the unfamiliarity between the community and the designers and, therefore, created a social distance. The designers were aware of the sensitive information that had to be discussed between the team and the community. Some of the required information included health, hygiene, habits, and very intimate issues that would impact how the designers approached the design solution. The designers were "foreigners" to the community and the design context. They needed to be contextualized in order to create a successful design. As a result, the community had to be sensitized to the designers' intentions, which would imply greater intimacy and ethnography between the designers and the community. The designers recruited a community partner to assist with the process of interviews.

The designers used mSurvey as a way to get direct feedback from the community. Contrary to the designers' assumption that the community would be more inclined to share information with a community member acting as a liaison, the general community did not feel comfortable sharing their sanitation habits and details with someone with whom they were familiar and who lived in the community. The community members also felt the same with the designers, with whom they were not that familiar and were foreign to the community. mSurvey was a necessary intervention, as many felt comfortable answering questions via text messages (FIGURE 4.9); it gave them a sense of anonymity. In Kenya, people who own a mobile phone use it for various transactions, such that it becomes a personal device with which they are comfortable using and they trust. Some of these transactions and activities include mobile banking, mobile health, and mobile farming, for gathering daily market prices about crops.

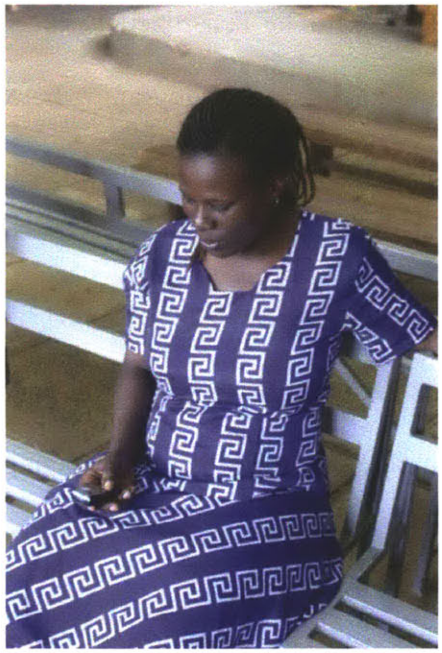


FIGURE 4.9: Woman taking survey through mSurvey in Kibera, Kenya

The mobile penetration in Kenya is extremely high, with SMS being the number one mode of communication (FIGURE 4.10).

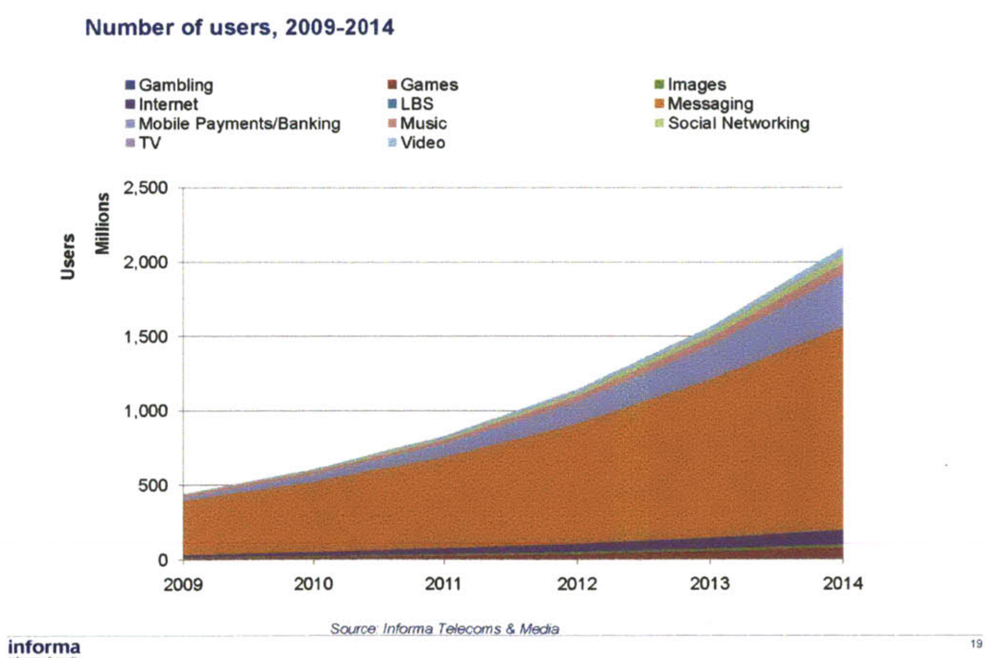


FIGURE 4.10: Chart showing SMS communication compared to other mobile communication

Unlike western cultures, where social networks are based on internet applications, SMS communication is predominantly used by multiple age groups. In developing regions, communication through mediums such as Skype and email is feasible, however, only in cyber cafes that are sporadically dispersed throughout the community and are costly. mSurvey was developed to facilitate free communication between the community members who wanted to offer feedback, and the designers receiving feedback. The goal was to develop a consistent dialogue between the designers and the community (FIGURE 4.11). Therefore, if the community had to pay to offer feedback, this would limit the interaction and reduce the design success.

After collecting feedback and becoming more familiar with the community, the designers had to remove a few assumptions, as expressed in the designer's feedback below, to be more effective and culturally aware designers.

One of the designers explained:

> *"The community viewed other sanitation solutions as less permanent solutions, which explained the lack of upkeep. The community wanted a solution that had a sense of permanence in the community." – designer's comments*

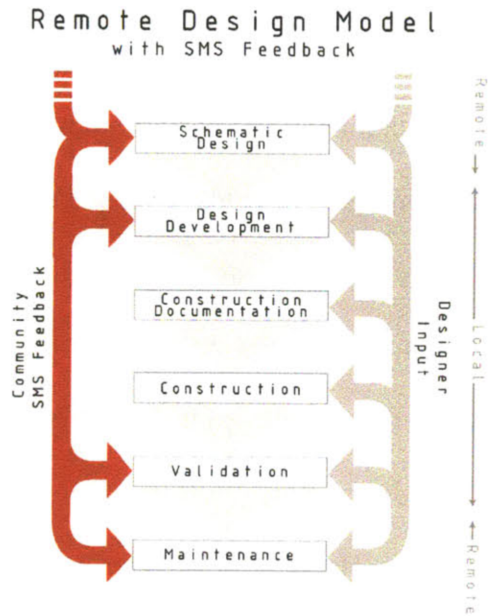


FIGURE 4.11: SMS communication in the remote design model

4.8 Interview with Designer

The author interviewed the lead designer on the team to get her feedback on the design process and designing for a community she did not know very well.

1. How long did it take to deploy your prototype (design + development)?

The sanitation center proof-of-concept prototype took 3 months from initial conceptual design to on-site deployment. The design team worked for over 2 weeks developing three design alternatives, each with a different set of design filters and assumptions about the user. All alternatives, however, shared quantifiable characteristics about the overall stall size being 5' x 3' to fit a squat style toilet, and a target cost of under $500 in order to qualify for a micro-loan, among others.

The first design was for a large complex of flush toilets with a separate stall for showers, allowing for gender separation and a payment/retail store. This facility was designed with the assumption that the toilets would be run by a community group and that the large complex would make each toilet to be cheaper in cost. Also, the team wanted to leave an option for flush toilets. Not knowing the cultural perceptions, the team thought that users may pay more for a flush option. (To allow the toilet water connection to the city water supply would require each facility to construct a new water line from the main road to the construction site.)

The second design alternative was for a cluster of small toilets/showers with local water supply. This facility was designed with the assumption that women and men would like to use separate facilities, and that each site would require at least two toilets. The design also incorporated a shower alternative for each unit, where the toilet could convert from a toilet to a shower when needed.

The third design alternative was for a pre-cast assembly for a single toilet with sub-floor dry collection barrels for waste collection. This facility was designed with the assumption that cost was the most limiting variable for the users, and that the most affordable solution would be the most realistic within this community, provided that it also had security, privacy and a convenient location.

Once the team arrived in Kenya, in the first week of July 2010, we re-evaluated the initial design assumptions per the actual end-user demands. This was achieved through a community forum and mobile survey. The forum component of the end-user assessment consisted of a series of open-ended questions pertaining to the depth of knowledge and understanding of their existing sanitation condition at the community level. This included, "Do you know where your waste goes?" and, "What do you hope to see changed about your current toilet facility?" The answers, as (we) predicted, were widely varied and gave great insight into the perceptions of the quality desired by the community, and allowed the community a chance to educate each other and express their concerns within a congregation of community members.

2. *How many prototypes did you deploy?*

In the summer of 2010, the team deployed two proof-of-concept toilets within the informal settlements around Nairobi, Kenya. The first toilet was placed within Kibera settlement, in the village of Soweto West. The second toilet was placed on a school grounds within Lunga Lunga settlement. The toilets warranted praise and increased demands from each of their respective communities, as they fulfilled the users' desires for privacy, security, and perceived cleanliness, along with being attractive and pleasant to use. Since the original two toilets were built in the summer of 2010, three more toilets have been built. The team continues to make and test adjustments to the original design, while building a more permanent local manufacturing facility. The future goal of the team is to deploy 60 toilets in Lunga Lunga by July 2012. This will warrant building a dedicated bio-gas digester, as well as, test the operational model of collecting waste on a daily basis to be processed into fertilizer and gas for purchase.

3. *How many community members actively participated in offering feedback via the mobile surveys? How many community members did you have total and how many different locations?*

During the first community forum in Kibera settlement in July 2010, there were 32 male community members and 7 female community members (39 in total) who provided feedback via mSurvey. Two surveys were conducted simultaneously, one for males and one for females. Each survey began with 7 matching demographic questions, and then 5 questions about routine and desired sanitation habits. These could be then cross-referenced and correlated between the males and females in the community. The last 5 questions in the male community member's survey, and the last 10 questions in the female community members' survey were unique. The males were asked questions about the behavior of the larger community, while the females were asked questions about the behavior of their children with regard to their use of toilets, (within the community women are the primary childcare givers), as well as, questions about the behaviors associated with female menstruation and pregnancy.

Within a later survey of the same community, there were 17 participants who provided feedback on similar questions pertaining to their bathing and showering habits and perceptions. This information was intended for use in the development of a shower alternative to the toilet construction.

4. *Was any of the feedback used in the subsequent design iterations? How would you describe the feedback loops?*

Yes, the information gathered from the community forum led to a selection of one of the design alternatives and forced the team to revisit the selected toilet design in order to adjust the design assumptions to accommodate the actual community needs. After the initial feedback, the third design alternative was selected for further design development. It was regarded as optimal to meet the most community needs and desires. In the process of taking the design from development to actual fabrication, feedback from local technicians and craftsman became critical to creating the most cost effective and repeatable manufacturing process. However, it was not until the first toilet was constructed that the team sought and received additional end-user community member feedback of the toilet and compared the end-user community members' experience to their previous demands. Responses from the operators and community members include: "Parents come to the school just to see the new [Eco-San] toilet, it is our new recruitment tool, now part of the school tour."; "It is so nice inside: light and clean. It is like a palace"; "This is nicer than my home. Can I have this for my home?" The feedback from the end-users is that the toilet satisfies the cost limitations, while providing an easy to clean alternative.

5. *Was there any verbal feedback from the community themselves with regard to offering feedback and the participatory design approach your venture took?*

Yes, the community forum was facilitated by a community group leader who took a very active role in volunteering feedback throughout the local design process, and helped to reword the questions within the survey to be best understood by the community (i.e. replacing "what is your gender?" with "Are you male or female?", and replacing "bathroom" with "toilet"). This community group leader later translated community feedback when clarity of outliers or translation from Kiswahili to English was desired. He also helped to lead the open-ended discussion during the community forum to help ease the community into talking with the design team by getting the group thinking about the topic and calling on individuals to speak out.

After the initial survey, many respondents asked to be notified when the toilet was in place so that they could use it, stating that they would be willing to provide feedback again when the time came.

6. *What are the implications/observations for keeping the client/user/customer so tightly coupled in the design process?*

The success and failure of the toilet relied on its favorability within the community; in order to scale the operation and deployment of the toilet, it necessitated that the community be willing to buy, operate and/or pay to use the toilet. Their [community] participation in the design process was necessary to achieve the most optimal design criteria. The feedback from the participation provided the design team the ability to assess which variables were most important and which could be left out to save on cost, leading to the most cost-effective and desirable toilet assembly. mSurvey and the forum lead to a sense of shared ownership in the design by the survey participants. This sense of ownership, and the community members' witness of the time taken to develop the prototype, ensured their pride in the toilet to the point that they promoted it within the community and ensured its good use.

7. *Any comments regarding how mobile surveys fell short of getting the information needed OR helped?*

Due to the sensitive nature of the information desired, pertaining to the most intimate activities of an individual's hygiene, the design team was required to use a mediated form of communication. mSurvey allowed participants to volunteer very personal and detailed information without exposing their identity, or being singled out. On future projects, regardless of the content of the survey, the design team will use a combination of mobile surveys, during the design development and assessment phases, and community forums and observation, due to the ease of processing and correlating information quickly, as well as, aiding in unbiased responses. When working within a remote design community, one different from that of the design team, we have found that most word of mouth responses will be spun positively or negatively based on the context of the question, including the interviewer themselves. (As a foreigner within a settlement, it is be assumed by most residents, that you are representing one of the hundreds of NGOs or missionaries in the community and, thus, can provide a service to them if they can only express enough need. This leads to the sometimes exaggerated stories about their condition or their telling of stories they have heard of others as their own.) Using mSurvey the variables that lead to bias responses (such as the anonymity of the interviewer) are limited and survey responses are more reliable and matter-of-fact. Also, because a cell phone number acts as a personal identification, responses can remain anonymous while allowing for a reliable means of reassessing the design with the same community over time and from a remote location.

8. *Kindly describe your initial assumptions before designing with the community. How did information from the community participation remove or reinforce those assumptions?*

The design team's initial assumptions about privacy and a willingness of users to pay more for a cleaner and more convenient toilet were validated from the mobile survey. We also received validation that a squat plate was the most desired form of toilet; because it is a shared community toilet community members do not want to touch a seat that has been used by someone else, and the squat plate provided a hands and seat free alternative. The design team learned that our assumptions about a waterless, no-flush toilet and gender separation being ideal was wrong. 6 out of 7 women said they would use the same toilet as a man. Affordability was preferred to these features of the toilet design, and they could be left out of the design.

We also learned that the community would be willing to invest in purchasing a toilet, only if they felt that it could be paid back and either turn a profit or save them money within the foreseeable future, and had perceived permanence. It is widely known that most of the residents of the slum do not own the land on or the home in which they live, so any new construction the design team proposed would need to be a temporary structure with an on-grade foundation or shallow foundation posts. Due to the lack of land/house titles, residents suffer from the threat of home eviction and, thus, prefer the security of a perceived permanent structure like concrete blocks over corrugated metal on bush pole. The third design alternative of a single low-cost, pre-cast assembly best satisfied the community desires, which included desired permanence of concrete, affordability of a waterless solution, and the flexibility to incrementally add more modules over time as demand and money allowed, among others.

4.9 Design Integration: Analysis of the Community engagement

This case study illustrates how mSurvey was particularly useful in getting sensitive feedback from the community. An example of a sensitive question asked is as follows (FIGURE 4.12):

Q8 What kind of toilet do you currently use?
1-"Free community" (5)
2-"Flying" (11)
3-"Pay" (12)
4-"Private" (2)
5-"other (text your answer)" (0)
Total: 30

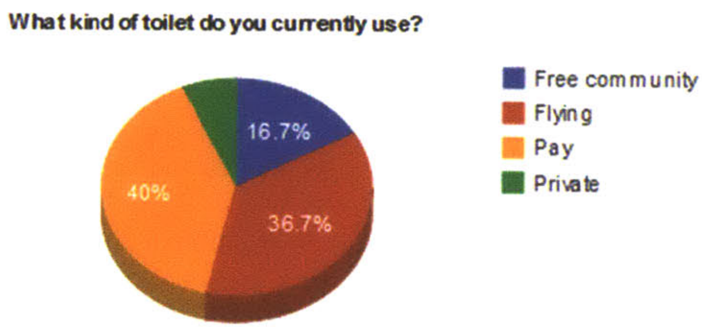


FIGURE 4.12: Responses from Kibera community using mSurvey

The designers found that over 93% of the community members used a toilet other than their own. This confirmed the lack of toilets and running water, which validated the designers' concern of limited plumbing in the community. The design had to compensate for the lack of plumbing if the team wanted to develop a solution quickly and robustly for the community.

Other sensitive questions included, how often community members washed their body (FIGURE 4.13). The implication of this question also helped in assessing the habits of the community members, with over 55% washing their bodies 5 days or less per week.

Q9 **How often do you wash your body each week?**
1-"2-3 days" (8)
2-"4-5 Every work day" (2)
3-"7 Every day" (7)
4-"On Sunday only" (0)
5-"Other (text '5' and answer)" (1)
Total: 18

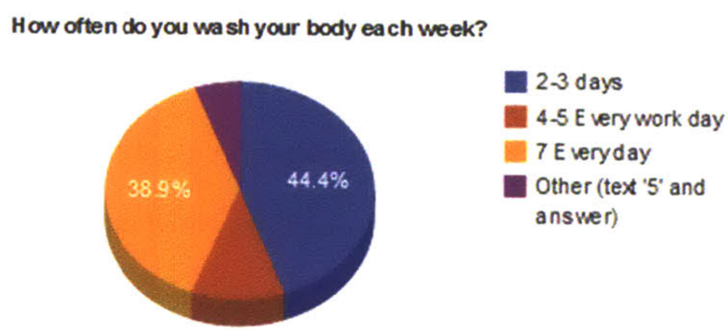


FIGURE 4.13: The ability to ask sensitive questions with a sense of anonymity

Although mSurvey was useful in capturing sensitive information in the form of text, it is important to note that the methodology was an added value, and did not replace the value of face-to-face conversations. Face-to-face conversations were important when developing aesthetics for the sanitation facilities; the community would have input about the look and feel of the design. mSurvey can however be extended to include the transfer of non-text data, known as Multimedia Messaging Service (MMS), which can include images and sound. The images would particularly be useful in developing surveys that are strictly based on images, rather than answering text-based survey questions. Unlike email and online surveys, which most of the community members do not have access to, the ability to send or receive an image using similar protocol to an SMS, is highly adaptable.

The designers were able to contextualize themselves based on a few minor variables used for understanding the community and the environment in which they would have to design. Some of the questions validated their assumptions and provided some clarity to the task before them. The designers discovered that over 60% of the community had to walk more than 2 minutes to the nearest facility, and 40% use pay-as-you use facilities, while 36% of the community members who participated in the design study use informal ways of using the bathroom. This was important to the designers as it reinforced the dire need for improved facilities. The feedback validated: 1) the need to scale quickly, based on the 60% that had to walk significant distances; 2) the need for a business opportunity or maintenance crew- 40% were regular users of pay-as-you-use services' and 3) the need for sanitation facilities- the absence of facilities result in 36% using informal ways.

The information received from the community using mSurvey helped the designers design with clearer objectives and fewer assumptions. Unlike most conventional relationships between designers and the end-user of the design, where the end-user could contact the designers for any change or modification in the design, the communication between the community and the designers was not that strong outside mSurvey. Therefore, the designers had to reduce as many uncertainties as they could in order to provide a sustainable solution for the community.

The design solution was successful as a result of both the use of mSurvey and the integration of the designers into the community. The designers conducted face-to-face interviews when they needed to, but used mSurvey to quantify assumptions that would impact their design. The designers had to design a solution that could scale throughout the community and, therefore, needed to quantify their design solution. The design of the facilities relied heavily on ethnographic research for customer "buy-in", which was necessary before implementation.

mSurvey facilitated depth of information in this study which impacted the design uptake by the community members. The study illustrated the correlation between the depth of information and end-user acceptance (FIGURE 4.14). Great understanding of the community was achieved through mSurvey which helped the design team design with greater confidence and understanding of context to develop a solution that would integrate into the community.

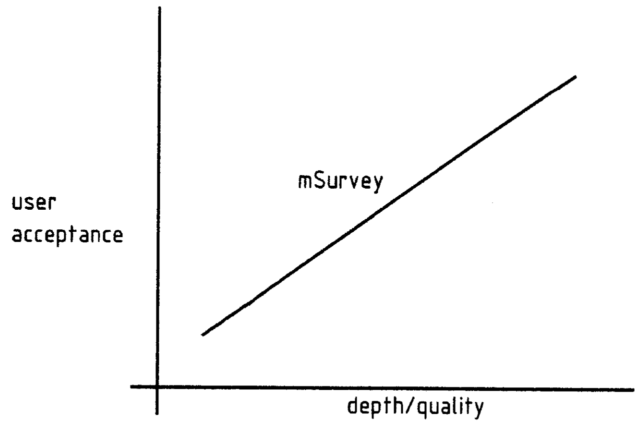


FIGURE 4.14: mSurvey offered depth of information to improve design quality

4.10 Contributions

The use of mSurvey proved to be useful when collecting information from community members in informal communities. mSurvey helped the designers filter sensitive information which would not have been difficult to gauge traditional face-to-face interviews. As noted, this case study was one that emphasized how mSurvey can be very helpful when conducting ethnographic research which requires sensitive information for design solutions to be embedded within the community.

CHAPTER 5

Systems Design in Emerging Markets: The Design and Distribution of Irrigation Pumps: A Tanzania Case Study

In this case study mSurvey was used to connect a set of global end-users to a company who designed, manufactured, and distributed products through 25 African countries. mSurvey closed the company's feedback loop for the purpose of gauging design impact directly from the end-user despite their complex distribution channels.

Systems design and systems dynamics in developing countries are difficult to undertake due to limited resources, infrastructure and technologies to manage each node or component that makes up the design. In the context of developing countries, products and services are designed and developed to be dispersed throughout many countries and communities with the intention to improve the quality of life of the end-users of these products. However, there are significant limitations to building robust systems designs, due to the lack or limitation of communication strategies and formal technologies to improve distribution channels and product designs for cultural and environmental sustainability.

Some products that are designed for multiple countries in Africa include, cook stoves, irrigation pumps, solar lamps, and architectural infrastructure such as precast building components. Most of these products are designed and manufactured externally in countries such as China and the United States with different cultures and systems in place; and imported to the regions of use. There are limited ways to assess utilization, and limited access to end-users for feedback and product improvement. As a result, research and development for improved designs is severely impacted by the absence of information that would enable designers to understand both systems dynamics and systems design, without the connection to end-users who utilize the products.

This case study involves Kickstart (the company), which designs, manufactures and sells irrigation pumps to be used by rural farmers throughout Africa. The company has country programs in Kenya, Tanzania, Mali, and Burkina Faso, and exports their pumps to multiple distributors and non-governmental organizations (NGO) working across Africa. This case study explains their design and development strategies, as well as, their current methodologies used to improve the relationship between their team and the end-users of the pumps. The case study illustrates how mSurvey was repurposed and used for both engaging the communities that purchased their irrigation pumps and to create an ongoing dialogue between the community and the design team, for proper design assessment and evaluation.

This case study aimed at illustrating the ongoing evolution of design and the channels that impact its distribution and continued development, rather than the static nature of a design that has been delivered and removed from the designers' control. It aimed at demonstrating the use of mobile technology as the medium for information sharing in remote regions where there is lack of a "personal computer", making the mobile device a new mode of personal computing.

5.0 Global: Tanzania, San Francisco, and China

Kickstart is headquartered in San Francisco with operations in over 25 African countries (FIGURE 5.0). The countries of operation range from extreme poverty to less extreme poverty. Most countries in Africa are highly agricultural and use farming as their primary source of sustenance and income. A few countries included in the company's distribution channels are Zambia, Uganda, Malawi, Sudan, and Rwanda; all with different histories of farming. Most farming is conducted in rural regions away from the city center, as seen in Kenya, where most farming is done at a distance of 90 miles or more from the city center. This case study takes place in Tanzania.

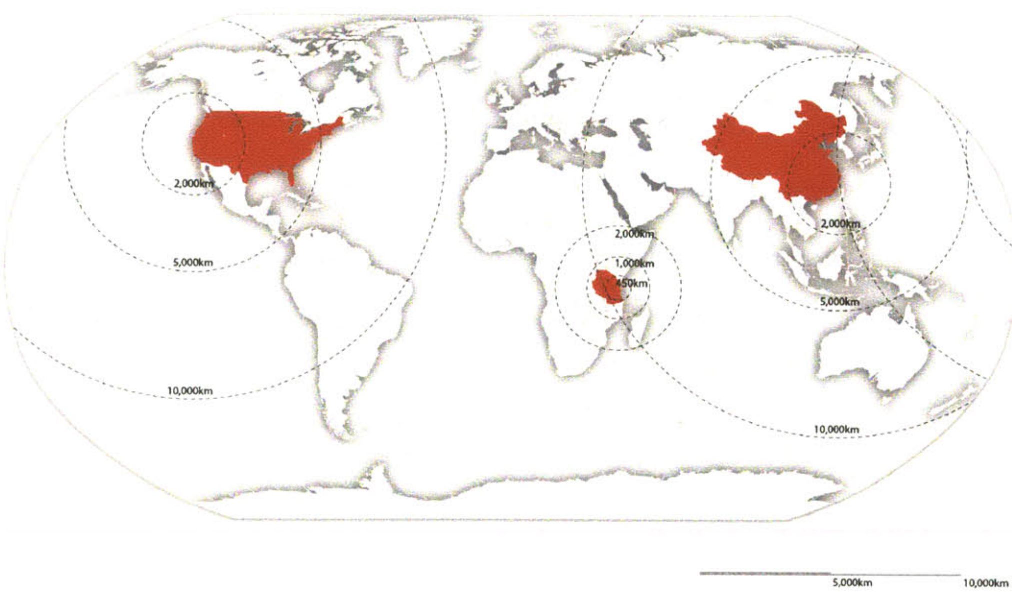


FIGURE 5.0: A globally operating company

Some of the major challenges which hinder farming in developing countries are access to water and access to electricity. As a result, some areas suffer from drought and poor irrigation systems. The opportunities to produce crops and to have sustainable farming operations are rare for these communities. This case study illustrates how one company followed the rule of designing with the community as part of their operations, in order to design a successful product, as noted by the company's vision:

> *Our team of engineers, designers, and technicians develop and test prototypes to ensure performance, cultural acceptability and durability. It takes many months to invent, design and produce each new technology.*

As the John Kinaga, Assistant Director of the company noted:

> *We mingle with ordinary citizens to identify their constraints, market demands and business enterprises that they can earn a living from. We then design and develop equipment geared at meeting the need. If the technology is already somewhere, we source it. If not, we have an entire department of engineering that can handle most innovation.*

5.1 Improving Product Design: Developing Context

Unlike the other case studies discussed, the research and development team in this case study were all part of an existing company with the goal of improving their impact and their product (irrigation pump) distribution throughout Africa. The company wanted to understand the end-users, the overall systems design, and systems dynamics. The design of the irrigation pumps was developed and implemented in 1996 with success of sales and distribution of over 188,000 irrigation pumps throughout Africa, at the time of this case study. As they scaled and grew throughout Africa, the operations became increasingly difficult for the company to assess product utilization and product end-users, who were highly dispersed in different regions of countries across Africa. The company needed to get design feedback, general information about the sustainability of the product, and a general distribution to meet market demand.

Conventional modes of communication, such as emails or ongoing face-to-face meetings, were not feasible due to the lack of formal infrastructure in the regions. As the company scaled, both formal and informal distribution channels were introduced, making it increasingly difficult to find the direct link to the end-user of the product. The lack of infrastructure and formal distribution channels drastically reduced the visibility of the end-users, which resulted in the company's reliance on business to business channels to source their products to respective customers (end-users), rather than the conventional business to customer channels for product improvement.

The company has over 160 employees including, mechanical engineers, industrial designers, MBAs, and supply chain strategists. The overarching goal of the company is to make a product that has sustainable outcomes in the different regions of its distribution. In the two preceding case studies, mSurvey was part of the initial conception, ideation, design and development of the design solutions. However, this case study was different in three ways:

1. The case study investigated the ongoing assessment and improvement of a design that had already been designed, packaged, and sold as a product.
2. The case study investigated how mSurvey improves systems design.
3. The case study investigated how mSurvey can be used for analyzing systems dynamics.

5.2 Distant Users: Developing Relationship with User for Design Input

The other case studies illustrate how data was needed to assess the concept and early design and development of the product. In this case study, the company aimed at designing a communication technology and strategy to make initial contact with the end-users of the product in order to improve design and distribution impact. The company had no visibility of their end-user base and product distribution. The company needed to confirm who their customers were before monitoring and assessing the product's design and impact.

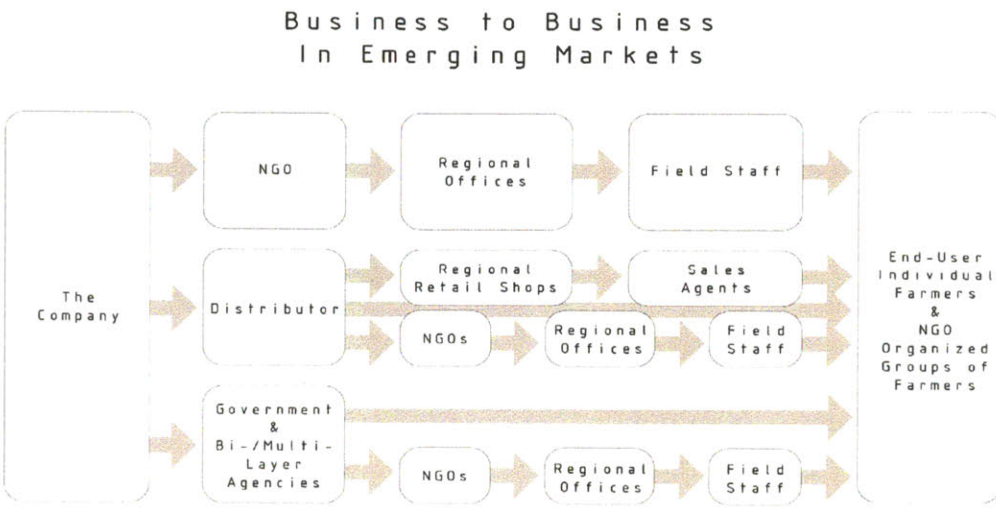


FIGURE 5.1: Typical business to business (B2B) operation and product distribution in developing countries

Their markets were dispersed. Headquartered in San Francisco, research and development in China, and business to business (B2B) distribution channels throughout Africa (FIGURE 5.1), the distance between research and development was significantly large, which affected the possible modes of feedback and communication from the end-user. It was also not economically feasible to have face-to-face meetings or locate all product end-users. Most of the community members that purchased the irrigation pumps and products had access to mobile phones, which is the single-most available technology in developing countries. The company and the author brainstormed ways to engage the end-user base utilizing mSurvey.

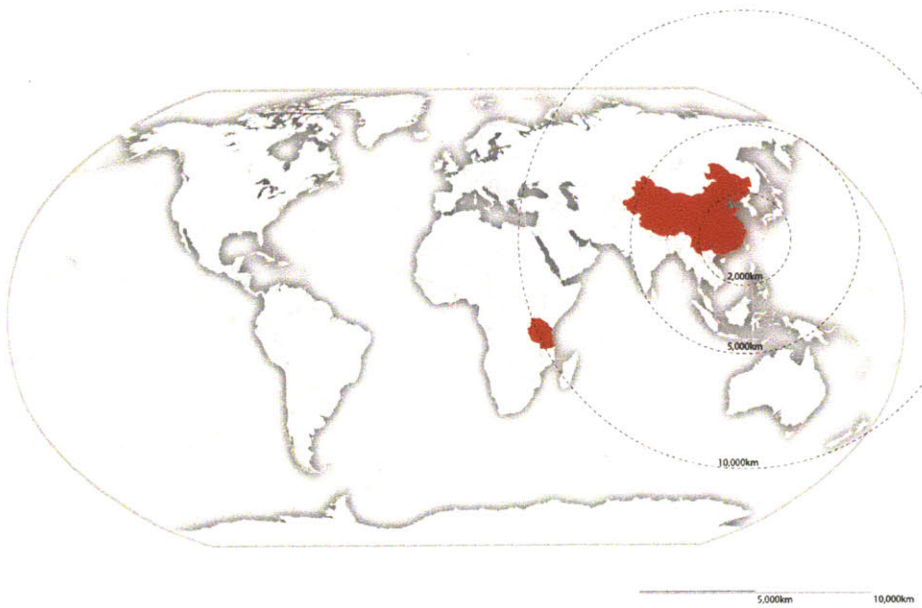


FIGURE 5.2: Distance from Tanzania to China manufacturing

The case study was implemented in Tanzania (FIGURE 5.2). Due to the limited infrastructure in many of the African countries, the company created business to business distribution channels. The B2B distribution channel is a process of importing the products to business partners in different countries, who were responsible for distributing the products within that country. Tanzania represented a typical example of the B2B relationship between the company, business partners, and product users. As part of the case study, a shipment of 1000 pumps was distributed through different channels in Tanzania, in order to get to the end-users of the product.

The products distributed were all irrigation pumps for farmers (FIGURE 5.3). The farmers were typically small-scale farmers who owned 0.3 hectares of land or less. The famers wanted to increase their yield, either for family and food self-sustainment or for income, and, therefore, needed a way to boost their agriculture production. The irrigation pumps were ideal because they were designed to draw water from a depth of 20 meters to a height of 7 meters above ground, which would be difficult to locate using conventional farming methods. Farmers were typically highly dependent on weather patterns which dictated the source of water to irrigate their crops. Due to the arid land in some regions, water was a very scarce commodity. The direct connection to a water source allowed the farmers to water their crops more frequently without the direct dependency on rain for improved agricultural yield. By utilizing the pumps, the farmers were able to predict and grow crops more effectively and productively.

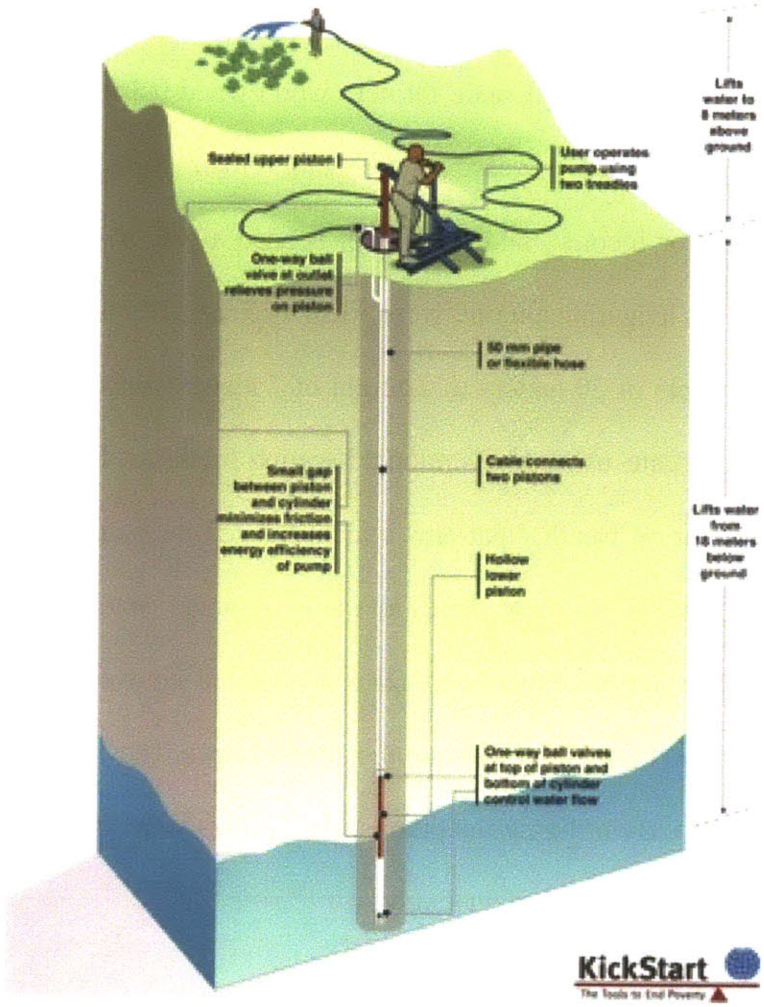


FIGURE 5.3: Irrigation pump from Kickstart (image provided by the company)

With distribution in 25 African countries, there were many unknown variables with the company's system's design and distribution channels. A critical unknown, yet important variable was the actual farmer who utilized their product. Other unknowns were, the location of the farmers (end-users), the location of the farms, the farm sizes, the water sources, how the end-user utilized the pump, and end-user demographic. The unknowns were major barriers to growth and overall sustainable impact of the products, which were major concerns of the company. The visibility of end-users became increasingly difficult and created a significant challenge to design improvement. The availability of "off-the-shelf" technologies and communication systems to provide end-user visibility were non-existent. Unlike other modes of communications observed in more conventional system designs, such as email, on-line surveys, customer service, product troubleshooting, or physical infrastructure such as roads and metro services, the company had to resort to novel ways of communication that would provide similar results and help assess the many unknown variables in the system's design.

Due to the complexities in the current distribution system, the presence of multiple unknowns resulted in a less-robust and less-attractive strategy for growth. The lack of end-user input hindered product improvement and lack of knowledge for future user communities based on geographical distribution. An innovation was developed on the core technology of mSurvey as part of the case study to close the feedback loop needed in the system's design.

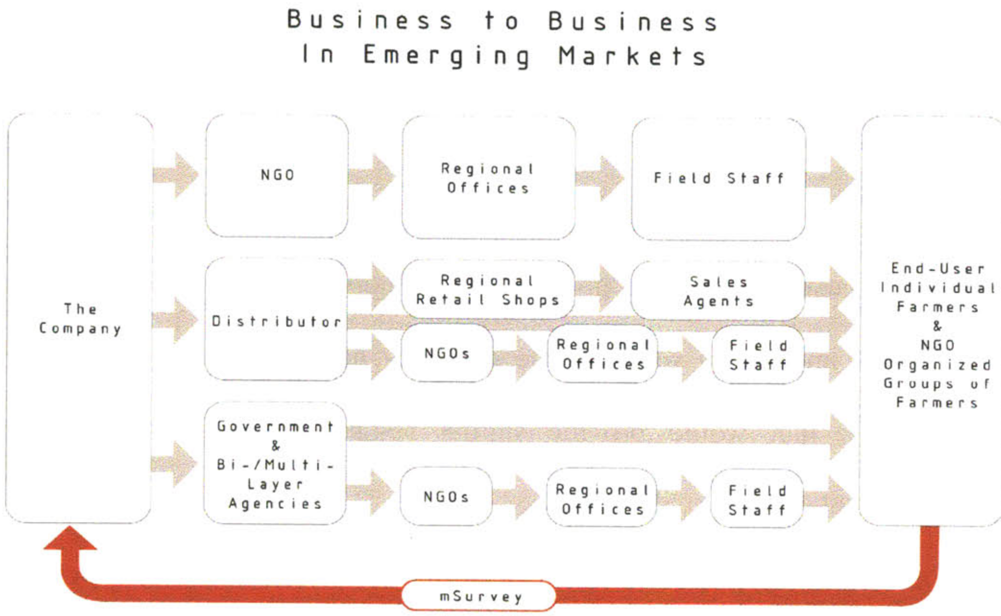


FIGURE 5.4: Improving the relationship between user and the company

5.3 mSurvey Connecting Users to R&D and B2B

The system developed using mSurvey was called an electronic product registration system. The system included an electronic warranty (e-warranty) card placed in each product used by the users in order to register a product. The registration of the product provided a means to:

1. Close the feedback loop (FIGURE 5.4)
2. Build end-user relationships
3. Have end-users drive growth and impact throughout regions which were difficult to assess and reach

Each electronic registration card was placed in the product guide of each product. After product purchase, the end-user would send a SMS to the mSurvey software, using a unique number located on the electronic registration card of the product. Once the end-user registered, the company was able to use the mobile number of each end-user in order to follow up on product utilization.

In August 2011 – September 2011, the e-warranty cards were designed and shipped to the distribution location in Tanzania where they were inserted into each product before being sold. At point of purchase, the new owner of the irrigation pump registered their product by following the instructions on the e-warranty cards. The company was able to view all registered end-users on the internet at the time of registration.

FIGURE 5.5: Product registrations on a smartphone (iPhone) in the US

The registration process continued for 4 months and is ongoing. The information for each end-user is available to the company for future communication and assessment. In October 2011, the company was able to connect with each end-user registered using mSurvey. It was possible to follow-up about the product purchase with questions about the product. The product registration process was used to close the loop between the company and the end-users. However, with further development, the registration process can be used to get a quick assessment of the end-users at registration through a 3 question questionnaire.

At the beginning of October 2011, the response rate for registered products had grown from 24% to 50% (FIGURE 5.5). The company had access and visibility to 50% of their end-users which was a significant boost from 0%. The case study provided interesting insight outside the scope of the case study. As the author and the company examined the data on personal computers connected to the internet, there were patterns that began to emerge. The company observed that registration peaked on Tuesdays. After further investigation, the company and the author concluded that Tuesday were "market" days and most farmers would do their purchasing on these days. Time of day was also observed; most frequently, farmers would register their irrigation pumps at early hours of the day.

5.4 Analysis: The Advantages of Feedback Loops

This case study offers a mode of communication to improve the systems designs for a company operating in developing countries. The company was able to get insight into their operations making them more efficient and effective. After getting an initial assessment of the end-users and an established communication line, the author met with the company to analyze the process and investigate future possibilities. At time of meeting, the end-user registration was at 24%. During the meeting, the discussion focused on ways of improving the system to understand where feedback loops were necessary in order to create better understanding of the systems design and dynamics.

The September (2011) meeting with the company included a supply chain strategist, marketing director, business development director, industrial designer, the assistant director, and the author.

The general consensus at the meeting was that:

mSurvey helped in understanding where the products were in Tanzania and connecting to end-users who were not visible or known to Kickstart

The meeting sparked many questions and a discussion on the use of mSurvey to improve their system's design and to integrate the process as a constant feedback loop. The company confirmed that the process would only be the beginning of a process for painting a holistic picture of their impact and distribution flows. The company developed interest in finding out more about the end-users and thought this could be done through specific questions. The questions would be generic and asked to every end-user that purchased a pump. The questions would include finding out the end-user's name- the company wanted to get to know their end-users and felt knowing their names would be more personable; the purchase date of the product— this would give them insight to the lead time of product purchase and distribution if an exact purchase date was recorded; the location where the product would be used— since the product was an irrigation pump, knowing where the pumps were used gives the company a geographical distribution of water resources in the region; and, later, how the product was used -knowing if the product worked for the intended reason of purchase.

To scale and make the system more universal, the company and the author would further develop the electronic registration cards within their manufacturing facilities in China, as part of the assembly-line process. Developing a universal system would enable all end-users to close the feedback loop within the system's design to potentially gauge the impact and design assessment of a significant percentage of their irrigation pumps.

mSurvey offered a level of access to the end-users which was absent in the distribution flow of their products (FIGURE 5.6). As a result, the team can carry-out assessment and evaluations as follow-up to the utilization of the design. The immediate access offered a way of gauging impact of the design.

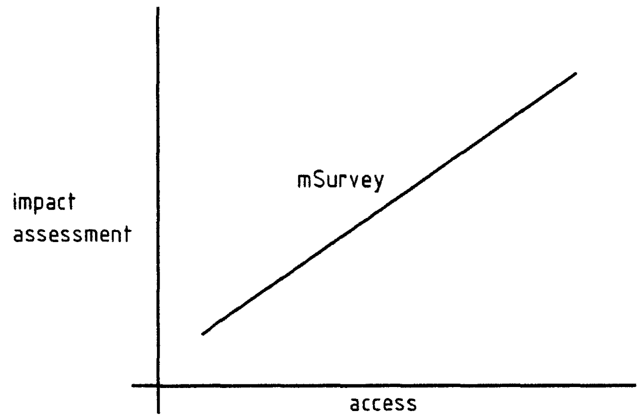


FIGURE 5.6: Initial access enables impact assessment

5.5 Contributions

The use of mSurvey connected the company and their end-users for the first time. The company has since scaled their operations to include new countries, such as Zambia and Malawi in order to improve their relationship with all farmers that purchase their products across Africa. By closing the feedback loop, the company has access to develop new technologies for the communities, as well as, improve their distribution, create awareness, and create greater access to their products across Africa.

CHAPTER 6

Information to Iteration: Design evolution

Illustration by: Terry Hirst
Source: ***Agroforestry in Dryland Africa***

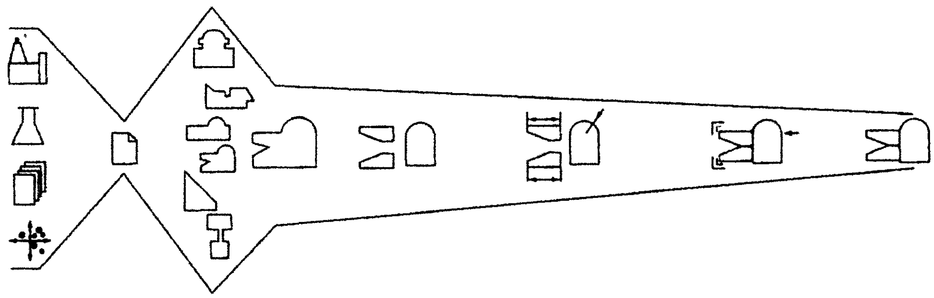
The illustration above expresses the "status quo" when designing in remote areas. mSurvey was developed to challenge the norm and create information channels for design and technologies to evolve as part of communities; and to sustain relationships from concept to continued utilization. mSurvey facilitates the evolution of ideas from nebulous projects to permanent design solutions within the community.

This study investigated the design process in different settings with different teams and different design goals. The study aimed at showing the similar challenges when designing for remote communities in resource-constrained regions with limited modes of communication. The study showed how mSurvey significantly improved the dialogue between the design teams and the communities. It found that improved channels of communication offered greater insight and clarity in the design goals, which resulted in improved design results or offered new knowledge for subsequent development for end-users. The communication channels improved the relationships with the end-users, who assisted the designers by offering information about context.

The implications for improved communication technologies and solutions to deliver information go beyond this body of work. Through this research and external observations, I discovered that the design process is not "frozen" or becomes complete once the design is delivered to the end-user (ramping up) as illustrated in traditional design settings.[46] In Eppinger's model (FIGURE 6.0), which shows Phase 0 – Phase 5 of a traditional product design process, we notice customer needs and feedback in Phase 1 and Phase 5, and no added information after the design is delivered. As a result, designs become static after Phase 5, once the design has been vetted and handed over to the end-user for utilization. Design outcomes tend to be more successful when there are fewer barriers to observation or communication.

[46] Eppinger, Product Design and Development , Third Edition

Design adjustments and evolution are tightly coupled with proximity between the designer and the end-user; therefore an additional design Phase becomes irrelevant. In this study, I prove by way of examples, design is an ongoing process and post engagement is necessary when the design is placed in a context of extreme distances from the designer. The study shows that communication is necessary from the stages of concept and development to placement and end-user utilization. This can be observed in the case study of Kickstart.



Phase 0: Planning	Phase 1: Concept Development	Phase 2: System-Level Design	Phase 3: Detail Design	Phase 4: Testing and Refinement	Phase 5: Production Ramp-Up
Marketing • Articulate market opportunity. • Define market segments.	• Collect customer needs. • Identify lead users. • Identify competitive products.	• Develop plan for product options and extended product family. • Set target sales price point(s).	• Develop marketing plan.	• Develop promotion and launch materials. • Facilitate field testing.	• Place early production with key customers.
Design • Consider product platform and architecture. • Assess new technologies.	• Investigate feasibility of product concepts. • Develop industrial design concepts. • Build and test experimental prototypes.	• Generate alternative product architectures. • Define major subsystems and interfaces. • Refine industrial design.	• Define part geometry. • Choose materials. • Assign tolerances. • Complete industrial design control documentation.	• Reliability testing. • Life testing. • Performance testing. • Obtain regulatory approvals. • Implement design changes.	• Evaluate early production output.
Manufacturing • Identify production constraints. • Set supply chain strategy.	• Estimate manufacturing cost. • Assess production feasibility.	• Identify suppliers for key components. • Perform make-buy analysis. • Define final assembly scheme. • Set target costs.	• Define piece-part production processes. • Design tooling. • Define quality assurance processes. • Begin procurement of long-lead tooling.	• Facilitate supplier ramp-up. • Refine fabrication and assembly processes. • Train work force. • Refine quality assurance processes.	• Begin operation of entire production system.
Other Functions • Research: Demonstrate available technologies. • Finance: Provide planning goals. • General Management: Allocate project resources.	• Finance: Facilitate economic analysis. • Legal: Investigate patent issues.	• Finance: Facilitate make-buy analysis. • Service: Identify service issues.		• Sales: Develop sales plan.	

EXHIBIT 2-2 The generic product development process. Six phases are shown, including the tasks and responsibilities of the key functions of the organization for each phase.

FIGURE 6.0: Design process in product design and development (image from Product Design and Development, Third Edition)

6.0 From Pre to Post design: Evolving with End-Users

When all three case studies were compared, the implications were evident that the framework for communication can be used for multiple stages of design and can improve the evolving use and utilization of design solutions.

Case Study One- Pre-design: Concept and Implementation (Agile Design) with User Participation

In Trinidad and Tobago, the design team specifically chose the Agile Software Model which offered the flexibility to make design changes that would reflect in subsequent releases of their mobile software. The increased channel of communication through mSurvey created an environment for the team to design more freely. Changes to their design would include the input gathered and aggregated through mobile communication from the end-user population of fishing communities. The Trinidad and Tobago case study illustrated how the increased frequency of information through mSurvey impacts design iteration.

Case Study Two- Pre-design: Concept, monitoring and Assessment, and Sensitive Information Sharing

In Kenya, the design team used sensitive information, which was difficult to gather using conventional modes, amassed by mSurvey from the community. The increased communication channel through mobile communication, offered a more acute context for the designers to develop a successful solution to be integrated with the community. This case study illustrated how mSurvey provided depth of information to improve design uptake by end-users.

Case Study Three- Post-design: Design improvement and Utilization

In Tanzania, Kickstart used mSurvey to gather information to improve their systems design in order to get products to the users. The communication channels helped to create an unprecedented connection with the product users. This case study particularly looked at the ongoing engagement of product users after the product is in the hands of the end-user. The case study is an example of the possibility of subsequent design development in product improvement after the design is in use After embedded in context, there are new innovations and design improvements that can spawn from the original design, creating a constant feedback loop (FIGURE 6.1). This case study illustrated how mSurvey offered access to information and created a means for accessing design impact and utilization.

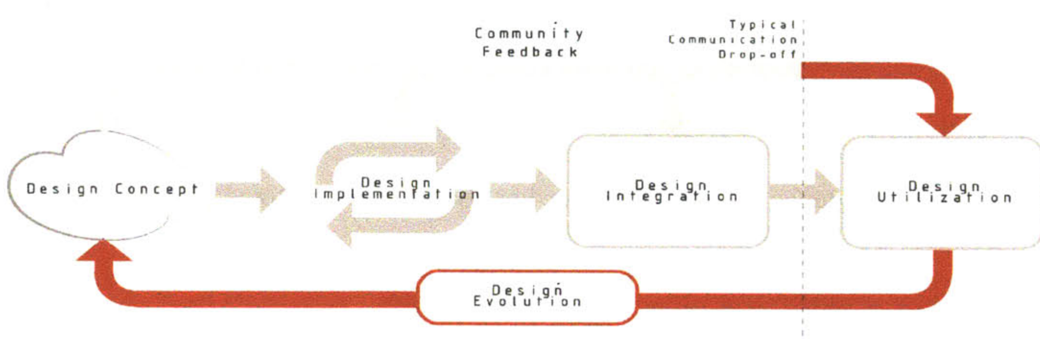


FIGURE 6.1: Design from concept to evolution

The case studies show that: 1) it is important for the designer to know about the context to become an informed designer; 2) information is important from many sources within the community for the designer to be able to design freely and confidently; and 3) the designer needs to be creative in improvising communicative approaches to acquire information that would drive the design process to ultimately derive solutions from the feedback gathered. For good design solutions, it is important for designers to understand the endogenous features of communities; by knowing the communities "know-hows" and their culture, the designer can once again become an expert of the design process.

Although the design teams were all different, and the context was also unique to each team, it was evident throughout this study that most design processes are alike and require improved communication between stakeholders. The design teams were highly dependent on end-user information for successful design outcome despite the stage of design.

Therefore, an observation that can be made in this study is that design is not a process removed from context. Design is a process that includes the active engagement of the designer and the end-user, so that a dialogue of shared experiences and information is made possible. The dialogue provides a framework for mental images and solutions to emerge in the minds of the designer. In order to make informed decisions, the designer has to be contextualized about his process as he externalizes his creativity to be inserted into a community of end-users. The context offers the designer the freedom to design with a sense of "know-how" and the ability to move from a single iteration to subsequent iterations.

The emphasis is, therefore, placed on how information is translated as meaningful variables with a technology which is tailored to access the necessary information about context. This study used mSurvey to create a meaningful dialogue between communities and designers to firstly gain access to communities, and secondly assess designs through a novel mobile application. As outlined in FIGURE 1.2 in this study, information is transmitted from the creator of the information (which can be end-user or designer) to the receiver of the information, in different formats and by different stakeholders using different technologies as explained in the mapping of the design process. Although these technologies offer a way of representing information in different ways, the fundamental exchange of information share significant similarities, until contextualized and represented to be comprehensibly understood by the receiver. However, the technologies currently in place in the design setting can be characterized as communication media tailored for the personal computer.

6.1 Information Representation: The Evolution of Design and Computation

This study does not attempt to reduce design to the use of mSurvey, but to introduce new stakeholders in the process with the use of mobile technology. This study used text information to show how information can impact design decisions once the information is distributed across multiple stakeholders. The personal computer has evolved. Information was once captured and displayed on view panels that once resembled small television screens, and have now shrunk to the size of one's palm. This compact size allows for more ways of sharing information on-the-go (mobile) to an exponential increased pool of stakeholders. Significantly large amounts of information are stored and computed remotely, making it accessible to be represented through many different ways on different modes of technology; whether as an excel file, transmission through a Skype call, or information represented on a hand-held device through SMS. The key is to understand the information that needs to be shared and how it should be represented in order for it to be consumed and be useful. The mobile way of computing has changed how we share information and will continue to bring about significant inclusion in decision making better design result only if the information represented is in a format that is intelligible to the receiver and has significant future applications.

CHAPTER 7

Intelligible representation of information

As an extension to this study, three experiments were conducted showing the multiple uses of end-user information entered through mSurvey. The experiments demonstrate how information can be used to relay meaning to the designer requesting the information and in turn can be made available to those interacting as end-users. The three experiments were, 1) connecting mSurvey to Rhinoceros[47] for visualizing information in geometric form, 2) connecting mSurvey to a drawing tool viewed by the designer on the web, 3) connecting mSurvey to a graphing tool used for evaluation and assessment of community information over time.

7.0 Drawing tool using mSurvey: connecting mSurvey to Rhinoceros

mSurvey was repurposed as a drawing tool for accepting end-user input. Using the method of input from end-users illustrated in the case studies, the questions were written to collect information about the end-user's surroundings. The utilization of this example would take place in low resolution areas where geographical positioning systems (GPS) were not available or the lack of vector housing data about a community. An end-user can walk around the perimeter of their home mapping out a floor plan of their house. The instructions were such that the end-user would let the system know in which direction a line needed to be drawn and the length of the line that should be drawn. The set of instructions were:

[47] Rhinoceros is a 3D modeling software used to develop spatial geometry

L: Left
R: Right
S: Straight
Followed by a numeric value.

The first question would ask the end-user to find a start position from where they would walk in a straight line along the perimeter of a building or a space with the letter 'S' and the number of steps taken. For example, if the end-user took 10 steps to an intersection, the end-user would enter S10. The 10 would be truncated to denote the distance in feet and the S to draw a straight line from the (X, Y, Z) point (0, 0, 0) in Rhinoceros. The end-user would then follow the perimeter by turning in a preferred direction and walking along the perimeter to gather the other lengths of the space. The information collected would define a spatial piece of geometry. An example of this would be: S10, L20, R22, R30, R32, R10 which would mean Straight 10 feet, Left 20 feet, Right 22 feet, Right 30 feet, Right 32 feet, and Right 10 feet, which would be a live feed in Rhinoceros to be drawn in real-time as geometry (FIGURE 7.0).

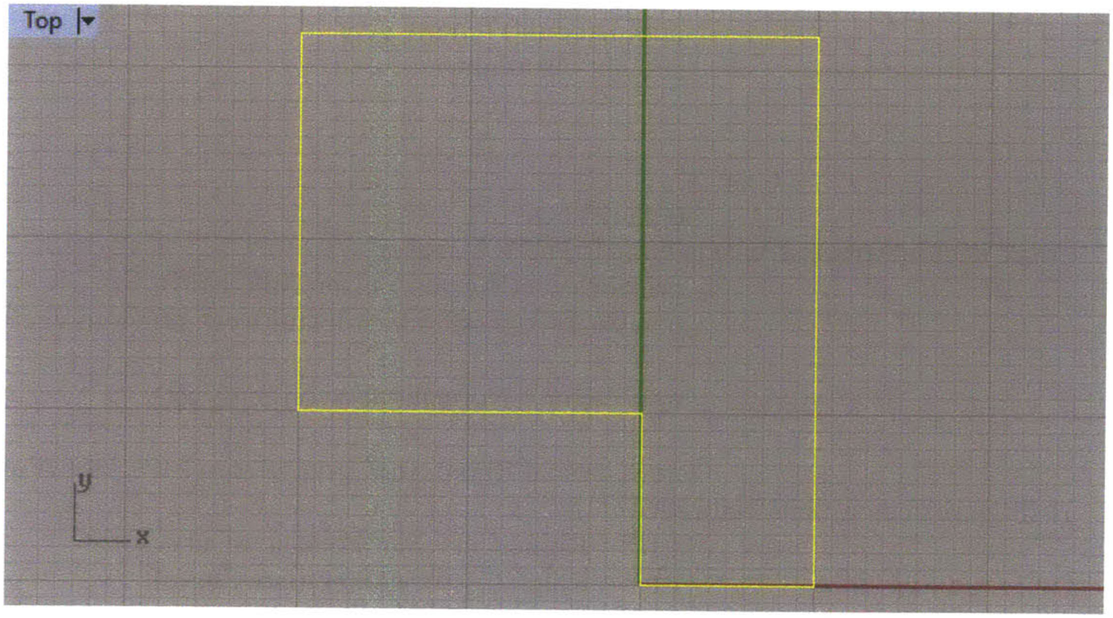


FIGURE 7.0: Geometric representation created by text input from mobile phone

The shared technology between the mobile communication sent from the end-users mobile phone and Rhinoceros was mySQL which stored all information received. Once the information was received, the information was directed to the geometry engine of Rhinoceros calling the following drawing functions based on end-user input.

Below is a snippet of the code written for this example:

```
objRecordSet.MoveLast
Do Until objRecordset.BOF
        dir = LCase(objRecordset.Fields.Item("direction"))
        dist = objRecordset.Fields.Item("distance")

        Select Case dir
                Case "s"
                        fstPt = Array(0,0,0)
                        lstPt = Array(0,dist*1,0)
                        newCurve = Rhino.AddCurve(Array(Array(0,0,0),
Array(0,dist*1,0)))
```

```
                    outline(count) = newCurve
                    straight = straight + 1


                Case "r"
                    defaultVect =
createVector(Array(lstPt(0),lstPt(1),lstPt(2)+1), lstPt)
                    previousVect = createVector(fstPt, lstPt)
                    newVect = CrossProduct(defaultVect, previousVect)

                    unitVector = NormalizeVector(newVect)

                    newCurve = Rhino.AddCurve (Array(lstPt, DrawPoint
(lstPt, unitVector, unitVector, dist*1)))
                    fstPt = Rhino.CurveStartPoint(newCurve)
                    lstPt = Rhino.CurveEndPoint(newCurve)
                    outline(count) = newCurve
                    Rhino.Print "Walking " + dist + " feet right"

                Case "l"
                    defaultVect =
createVector(Array(lstPt(0),lstPt(1),lstPt(2)+1), lstPt)
                    previousVect = createVector(fstPt, lstPt)
                    newVect = CrossProduct(defaultVect, previousVect)

                    unitVector = NormalizeVector(newVect)
                    unitVector = VectorReverse(unitVector)

                    newCurve = Rhino.AddCurve (Array(lstPt, DrawPoint
(lstPt, unitVector, unitVector, dist*1)))
                    fstPt = Rhino.CurveStartPoint(newCurve)
                    lstPt = Rhino.CurveEndPoint(newCurve)
                    outline(count) = newCurve
                    Rhino.Print "Walking " + dist + " feet left"
            End Select


            count = count + 1
            ReDim Preserve outline(count)
            objRecordset.MovePrevious


        Loop
```

It is evident that a few assumptions had to be made about the end-user spaces. These assumptions were that the space would mainly be orthogonal without curvature, and that a step would equal 1'-0". The experiment was used to get a sense of shape as well as the general area of someone's living quarters.

7.1 Short Message Drawing Tool for the web

Another example of connecting the live feedback from the end-user was through a web interface. The web interface allowed the person viewing on the internet to see the drawing of the end-user in real-time. mSurvey was integrated with a javascript drawing library written as part of this experiment. As the end-user entered information (S6 L10 R10 R20 R15 L7 R3 R15) the web tool would graphically display the information below (FIGURE 7.1).

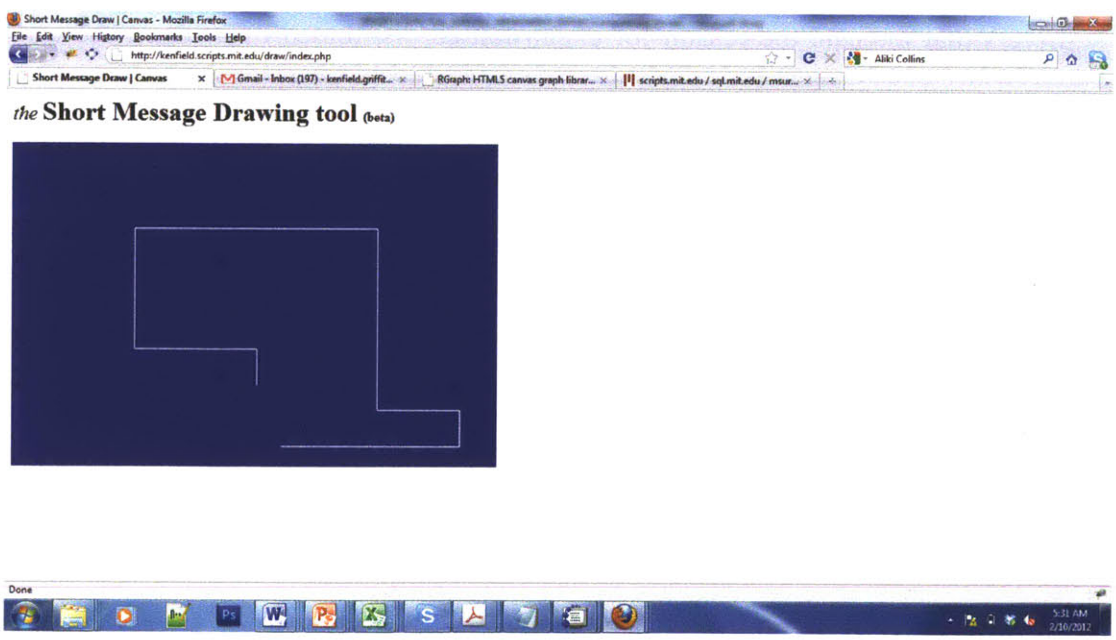


FIGURE 7.1: Visual representation of floor plan using web services from mobile phone

This allows the viewer to get a snapshot of the end-user's space in real-time. Unlike the Rhinoceros example, this experiment constructed an image rather than geometry. However, the two examples show how the information entered by the end-user can be used in muliply display platforms. This example shows how the information can be overlaid on a map of the end-user's location if the coordinates of the end-user can be described, entered, of gathered through telecommunication traingulation.[48]

7.3 Incremental Housing Assessment

The third experiment conducted was the development of a graphing tool that demonstrated the incremental growth of housing within a community in a developing country. It is studied that most housing infrastructure in developing countries are constructed in stages by the owner of the house.[49] There are a few drivers that indicate the reason for expansion all distributed over time. The drivers can include size of family or household income that would correlate with the time a new floor might be added to the basic structure of the house. In this experiment it demonstrates how end-users can offer input at intervals throughout the years or as granular as months. The questions asked would be:

What is the size of your family? – if this increases or decreases from previous end-user input from the month or year prior, one would have a snapshot of the family growth

[48] A mobile user can be located based on their distance between the three nearest towers

[49] Taken from an MIT course in Spring 2010, 4.232J/11.444J *Incremental Housing* taught by Dr. Goethert

How much money did you make this month? – in comparison with the previous month, the end-user response would illustrate their financial stability indicating if there has been any improvement in the quality of life for the end-user

Have you expanded your home? – if the end-user responded 'yes' the branching logic would direct them to answer the following question

How many floors? – the end-user would then state how many floors they expanded

Collectively, when the information is overlaid (FIGURE 7.2), it would paint a picture of the activities of the community and can eventually be shared with the community as community statistics. The graph shows household income, the years information was entered, number of persons in the home, and the number of floors (FIGURE 7.2). In the future, end-users will be able to send snapshots of images to show their incremental progress to develop a real-time time line of the housing progress with limited intervention for processing the information. The information would be processed using remote means of computation. Images will be cross-referenced to demonstrate which communities have the fastest development processes and why. The indicators can also include real-time semantic processing of internet data that point to possible historic occurrences which might have impact the development process. Some examples of this would be political decisions, economic influx, a progressive movement, or other.

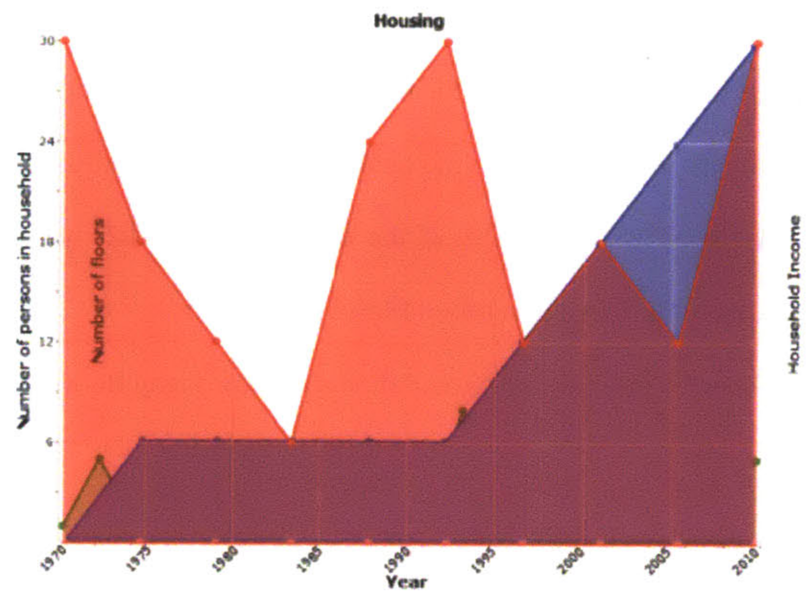


FIGURE 7.2: Visualization of incremental housing growth over time entered by end-user

The three experiments demonstrate the flexibility mSurvey offers and the shift in the ways design information is collected and distributed. mSurvey creates a platform for the collection of information as well as the sharing of information. In the case studies and experiments discussed in this study, the information collected was part of the design process and the process of mSurvey included end-users as the drivers of the information. The study did not discuss the future potential of end-users to query the collected information as one would if they needed to "ask a question" on the internet. The collection of information collected using mSurvey is hosted on remote servers which are networked resources. As end-users use USSD seen in banking queries, so can they with the information gathered about their communities. The information can be shared with individuals who are connected through technologies ranging from telecommunication connection to internet connection not having to depend on the infrastructure barriers that currently stagnate internet penetration.

There are many other applications that can be developed using the mSurvey approach and this might just be the beginning of representing information to multiple end-users through mobile communication.

Additional areas for research

Social cues in communicating

mSurvey offers great potential to communicate with community members via short messages. However the current use of mSurvey is to quantify the feedback from communities and correlate responses to questions that offer insight about communities. Designing is a rigorous process and demands engagement beyond mSurvey. In the design process, end-users need to offer qualitative feedback which is limited in the dialogue currently made available with the use of mSurvey. Although end-users can give input on an image, the feel of a design, or the look of a design, quantitatively; social cues (body language) are very important in assessing design quality. In face-to-face assessments, social cues and nonverbal communication can offer additional information about the design which may lead to additional "on the fly" questions not generated and automated through mSurvey. Some of these cues are voice intonation, facial expressions, and eye contact that offer emotional expression about and attachment to a design. As Mehrabian[50] expressed through the field of psychology, feelings or an attachment can be categorized as the 3 V's; verbal, vocal, and visual liking, which mSurvey does not

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[50] Mehrabian A., Silent Messages: Implicit Communication of Emotions and Attitudes (1972)

quantify in its current state. Although mSurvey offers a way for verbal input through short messages, it does not offer the vocal or visual elements of assessing cues, but may be used in parallel to know what variables can be assessed using each approach; whether face-to-face or mSurvey.

Spontaneous feedback

Technically, mSurvey was developed for designers to engage end-users in offering feedback about context at the point of contact (opt-in). In its current version, the tool does not offer a way for communities to offer spontaneous feedback or observations which can be very useful. If email is considered and compared as a mode of communication to mSurvey, an end-user using email can make an observation independently and send information about the observation without being cued for an answer. mSurvey triggers the thought process and relies on the end-user to answer specific questions related to the context. The system is not open to accept ongoing feedback from end-users compared to the independent feedback that email communication offers. However, noting this difference, in future development, it is possible to examine how mSurvey might be able to offer a channel of communication for spontaneous feedback by end-users who are not connected to email.

Scaling across cultures and telecommunication networks

One of the significant hurdles encountered when developing the mSurvey technology, is its ability to scale across countries and networks while being free to the end-users entering information. As a result, the technology had to be tied directly to the network of specific telecommunication providers to make scaling feasible. mSurvey was first developed in contexts where mobile phone penetration is particularly high such as East Africa and the Caribbean. In other regions where mobile communication is not as high poses a problem with accessing and getting feedback from far to reach communities. The new challenge is to provide a technology that would integrate into the culture when the mobile communication becomes more prevalent, and make mSurvey more accessible. From a conversation with a gentleman in the field in Cambodia[51] the next steps would be to make the technology representative of the culture in which it is deployed—how mSurvey can incorporate different characters for different languages spanning from Kanji (Japanese characters) to Hindi alphabet. The Caribbean and East Africa case studies are not representative of the different cultures there are for global feedback. However, I suspect the different encounters with other cultures outside the case studies illustrated in this study will lead to new developments and discoveries on how end-users interact with mSurvey as a technology.

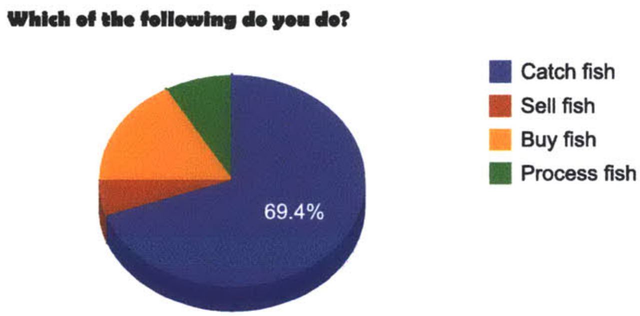
[51] Iwan Baskoro is a GERES senior expert on improved cook stoves based in Cambodia

APPENDIX

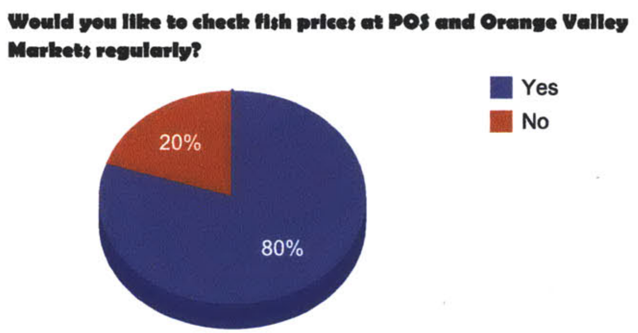
Chart   Visualize

You have selected a *Chart*

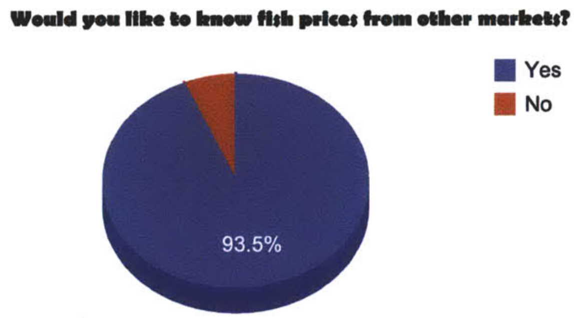
Q1 Which of the following do you do?
1-"Catch fish" (25)
2-"Sell fish" (2)
3-"Buy fish" (6)
4-"Process fish" (3)
Total: 36



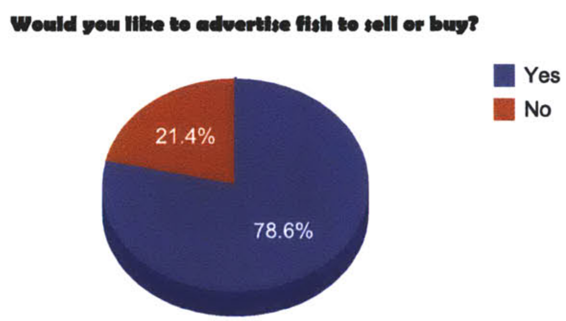
Q2 Would you like to check fish prices at POS and Orange Valley Markets regularly?
1-"Yes" (28)
2-"No" (7)
Total: 35



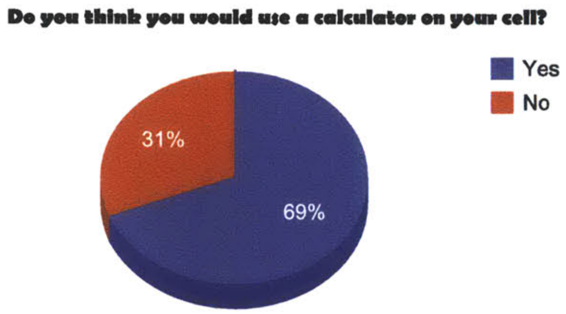
Q3 Would you like to know fish prices from other markets?
1-"Yes" (29)
2-"No" (2)
Total: 31



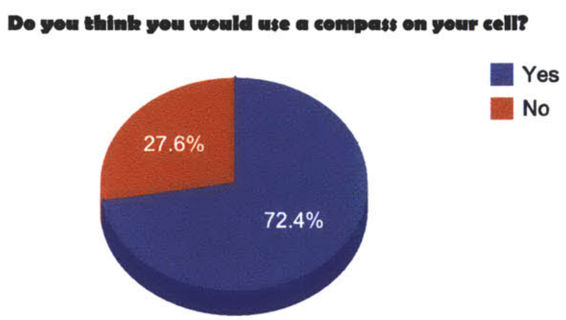
Q4 Would you like to advertise fish to sell or buy?
1-"Yes" (22)
2-"No" (6)
Total: 28



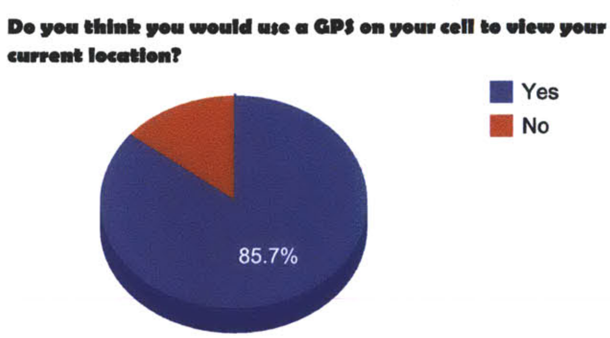
Q5 Do you think you would use a calculator on your cell?
1-"Yes" (20)
2-"No" (9)
Total: 29



Q6 Do you think you would use a compass on your cell?
1-"Yes" (21)
2-"No" (8)
Total: 29

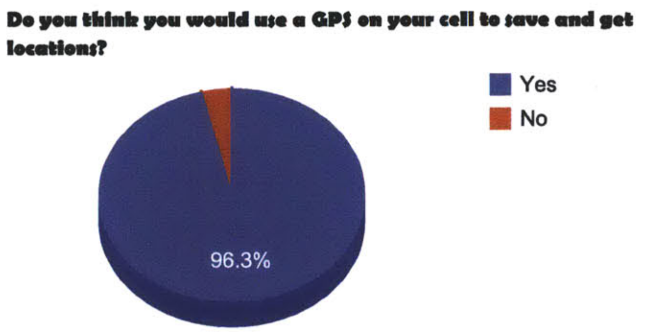


Q7 Do you think you would use a GPS on your cell to view your current location?
1-"Yes" (24)
2-"No" (4)
Total: 28

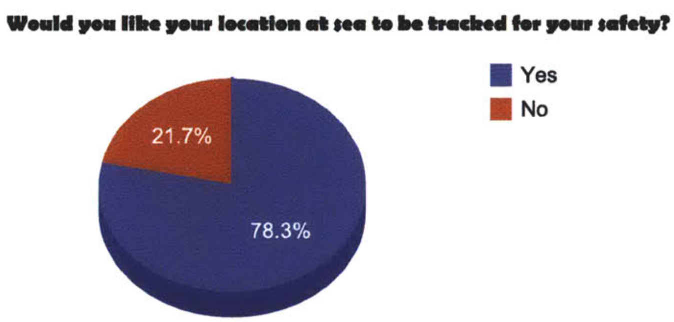


Q8 Do you think you would use a GPS on your cell to save and get locations?
1-"Yes" (26)
2-"No" (1)

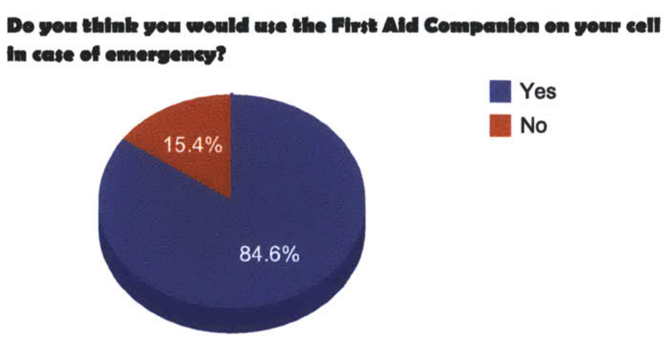
Total: 27



Q9 Would you like your location at sea to be tracked for your safety?
1-"Yes" (18)
2-"No" (5)
Total: 23

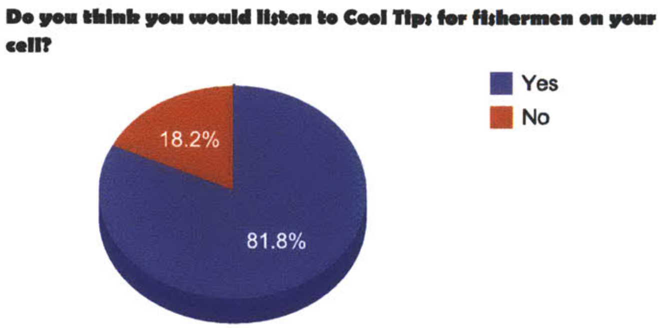


Q10 Do you think you would use the First Aid Companion on your cell in case of emergency?
1-"Yes" (22)
2-"No" (4)
Total: 26

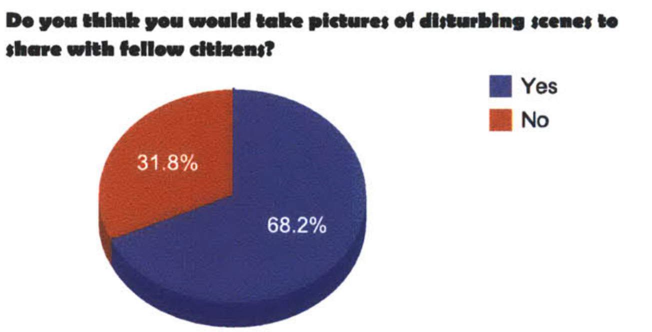


Q11 Do you think you would listen to Cool Tips for fishermen on your cell?

1-"Yes" (18)
2-"No" (4)
Total: 22



Q12 Do you think you would take pictures of disturbing scenes to share with fellow citizens?
1-"Yes" (15)
2-"No" (7)
Total: 22



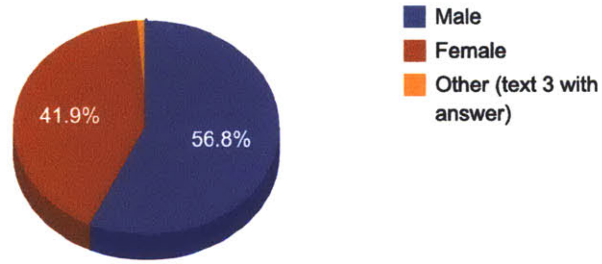
Contact mSurvey™

Chart   Visualize

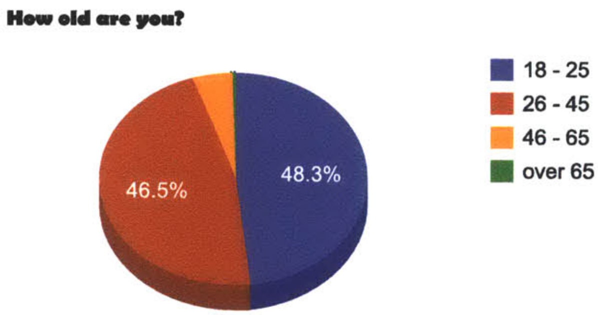
You have selected a *Chart*

Q1 Are you male of female?
1-"Male" (130)
2-"Female" (96)
3-"Other (text 3 with answer)" (3)
Total: 229

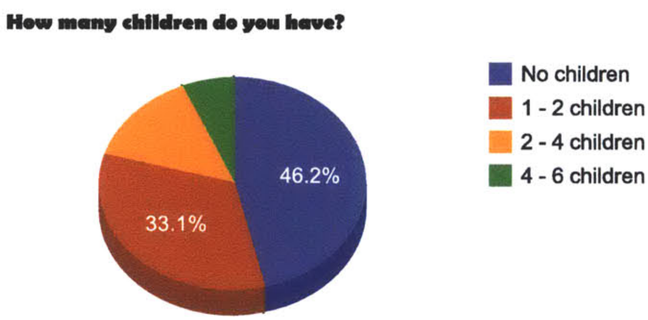
Are you male of female?



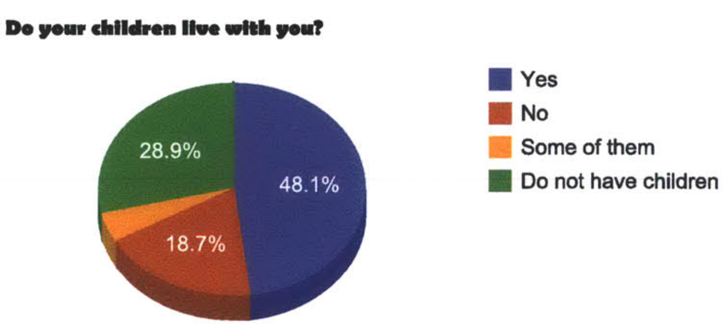
Q2 How old are you?
1-"18 - 25 " (111)
2-"26 - 45" (107)
3-"46 - 65" (11)
4-"over 65" (1)
Total: 230



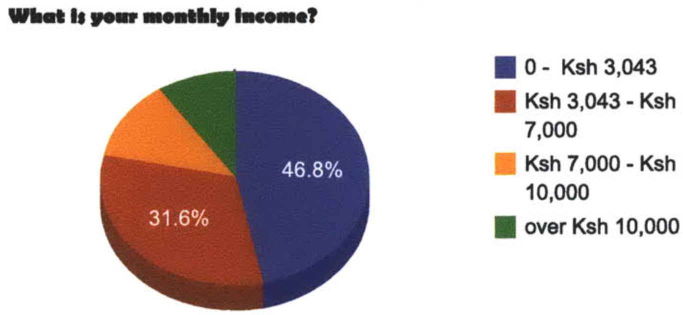
Q3 How many children do you have?
1-"No children" (116)
2-"1 - 2 children" (83)
3-"2 - 4 children" (36)
4-"4 - 6 children" (16)
Total: 251



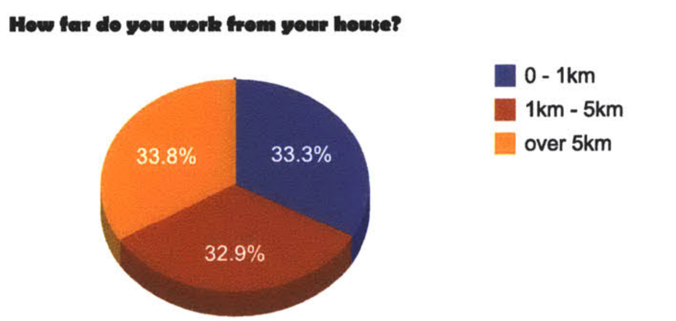
Q4 Do your children live with you?
1-"Yes" (113)
2-"No" (44)
3-"Some of them" (10)
4-"Do not have children" (68)
Total: 235



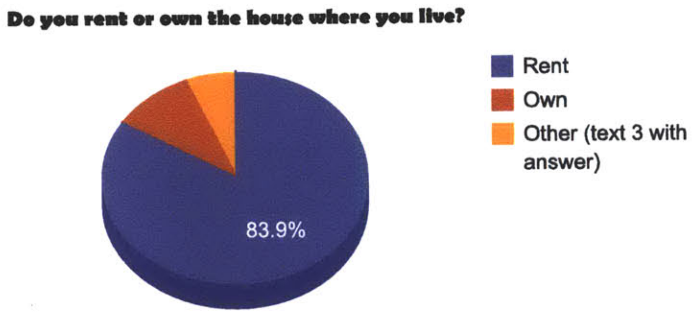
Q5 What is your monthly income?
1-"0 - Ksh 3,043" (108)
2-"Ksh 3,043 - Ksh 7,000" (73)
3-"Ksh 7,000 - Ksh 10,000" (28)
4-"over Ksh 10,000" (22)
Total: 232



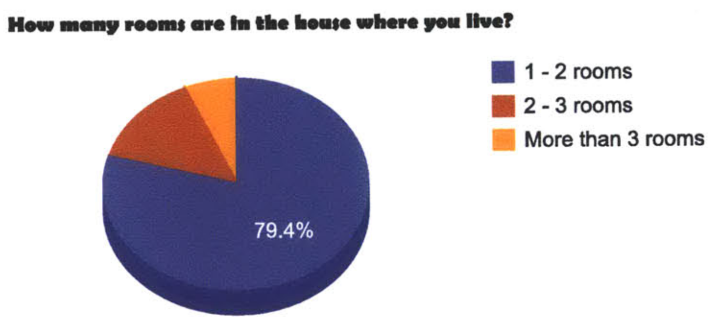
Q6 How far do you work from your house?
1-"0 - 1km" (80)
2-"1km - 5km" (79)
3-"over 5km" (81)
Total: 240



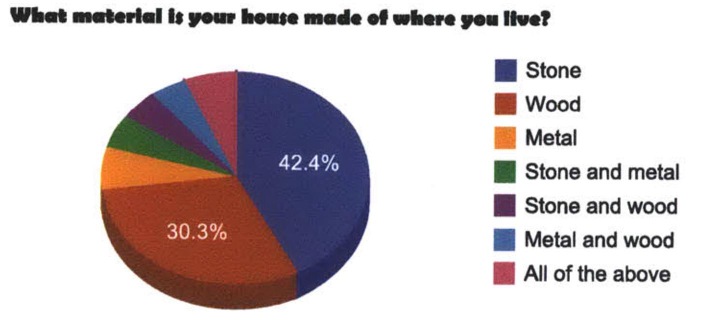
Q7 Do you rent or own the house where you live?
1-"Rent" (193)
2-"Own" (23)
3-"Other (text 3 with answer)" (14)
Total: 230



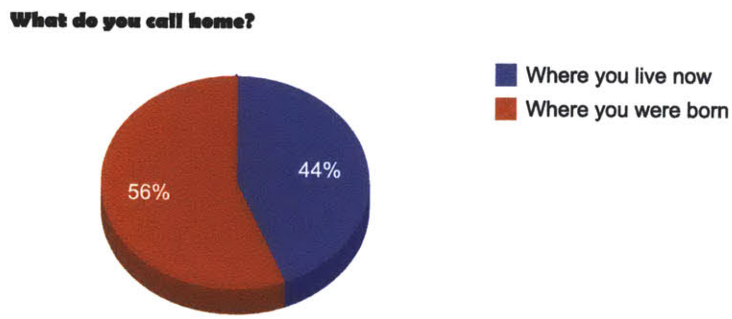
Q8 How many rooms are in the house where you live?
1-"1 - 2 rooms" (208)
2-"2 - 3 rooms" (37)
3-"More than 3 rooms" (17)
Total: 262



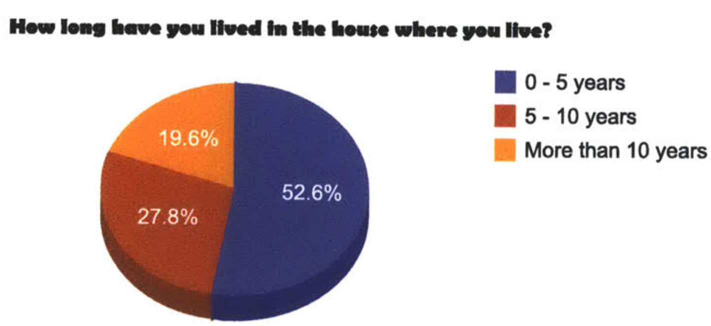
Q9 What material is your house made of where you live?
1-"Stone" (98)
2-"Wood" (70)
3-"Metal" (15)
4-"Stone and metal" (12)
5-"Stone and wood" (11)
6-"Metal and wood" (10)
7-"All of the above" (15)
Total: 231



Q10 What do you call home?
1-"Where you live now" (91)
2-"Where you were born" (116)
Total: 207

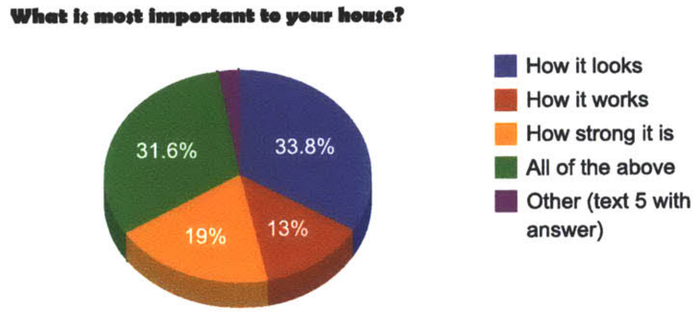


Q11 How long have you lived in the house where you live?
1-"0 - 5 years" (121)
2-"5 - 10 years" (64)
3-"More than 10 years" (45)
Total: 231



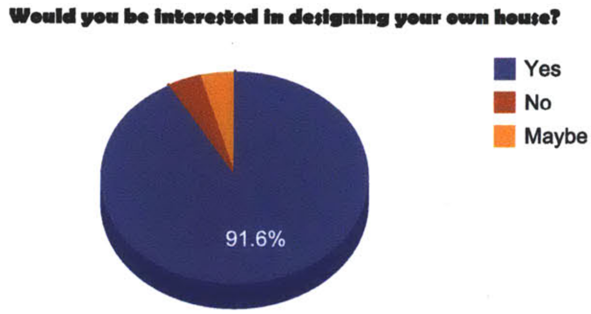
Q12 What is most important to your house?
1-"How it looks" (78)

2-"How it works" (30)
3-"How strong it is" (44)
4-"All of the above" (73)
5-"Other (text 5 with answer)" (6)
Total: 232

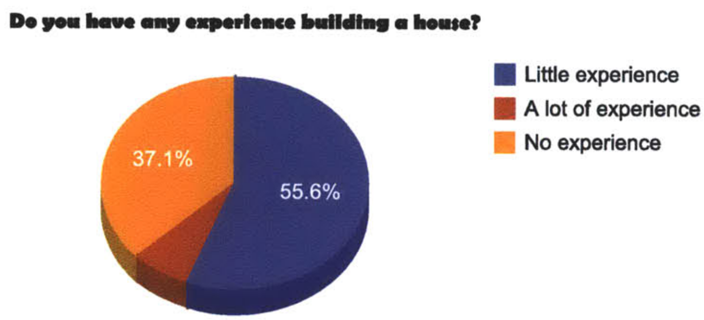


Q13 Would you be interested in building your own house?
1-"Yes" (208)
2-"No" (7)
3-"Maybe" (8)
Total: 223

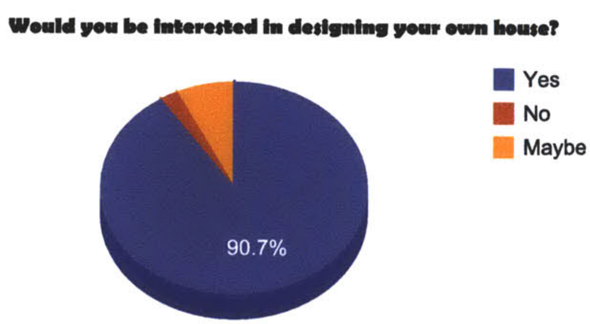
Q14 Would you be interested in designing your own house?
1-"Yes" (207)
2-"No" (9)
3-"Maybe" (10)
Total: 226



Q15 Do you have any experience building a house?
1-"Little experience" (129)
2-"A lot of experience" (17)
3-"No experience" (86)
Total: 232

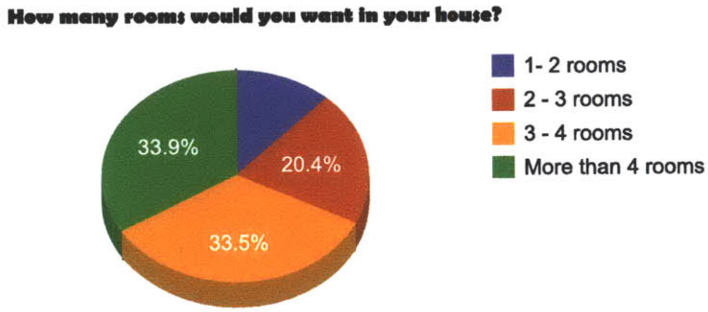


Q16 Would you be interested in designing your own house?
1-"Yes" (205)
2-"No" (5)
3-"Maybe" (16)
Total: 226

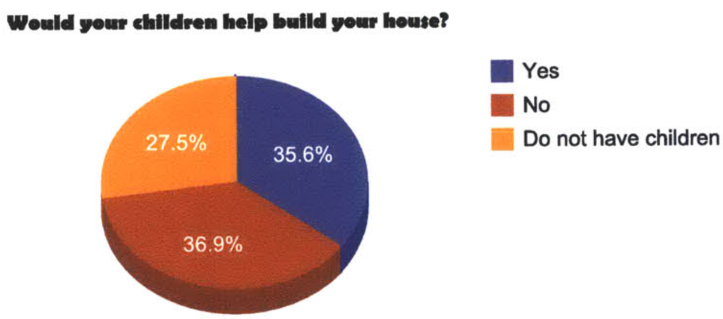


Q17 How many rooms would you want in your house?

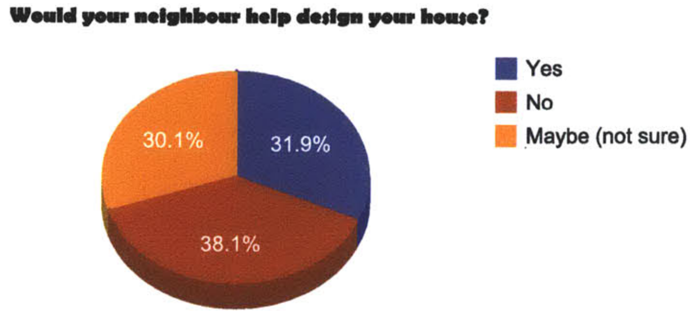
1-"1- 2 rooms" (30)
2-"2 - 3 rooms" (50)
3-"3 - 4 rooms" (82)
4-"More than 4 rooms" (83)
Total: 245



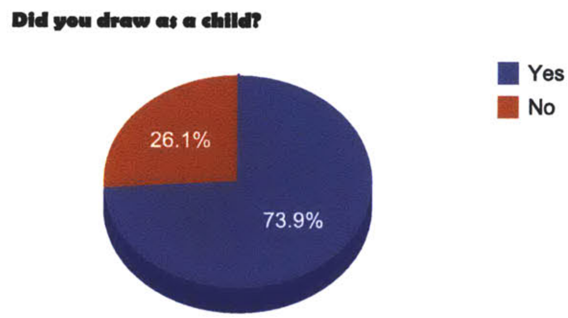
Q18 Would your children help build your house?
1-"Yes" (79)
2-"No" (82)
3-"Do not have children" (61)
Total: 222



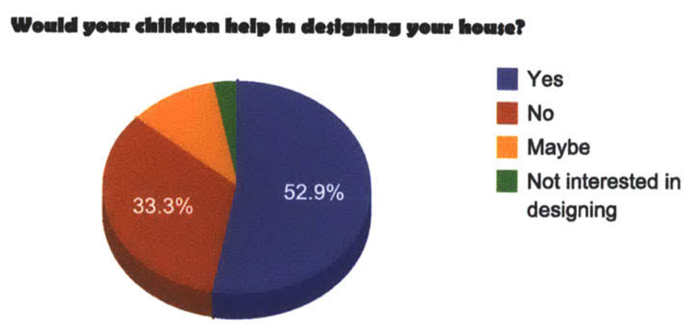
Q19 Would your neighbour help design your house?
1-"Yes" (72)
2-"No" (86)
3-"Maybe (not sure)" (68)
Total: 226



Q20 Did you draw as a child?
1-"Yes" (161)
2-"No" (57)
Total: 218

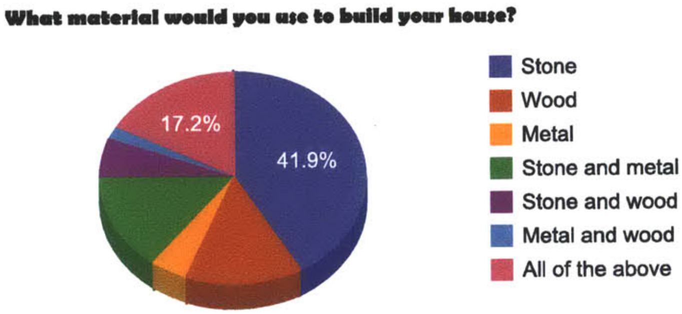


Q21 Would your children help in designing your house?
1-"Yes" (119)
2-"No" (75)
3-"Maybe" (24)
4-"Not interested in designing" (7)
Total: 225

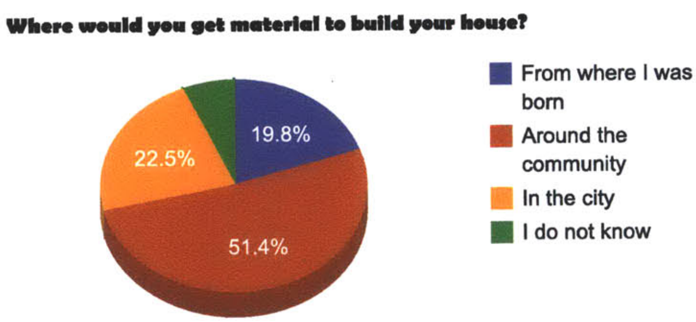


Q22 What material would you use to build your house?

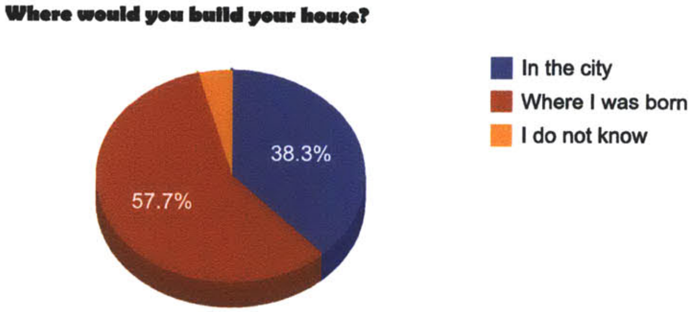
1-"Stone" (95)
2-"Wood" (32)
3-"Metal" (10)
4-"Stone and metal" (33)
5-"Stone and wood" (14)
6-"Metal and wood" (4)
7-"All of the above" (39)
Total: 227



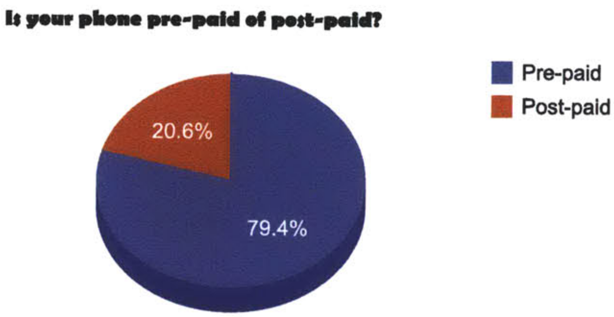
Q23 Where would you get material to build your house?
1-"From where I was born" (44)
2-"Around the community" (114)
3-"In the city" (50)
4-"I do not know" (14)
Total: 222



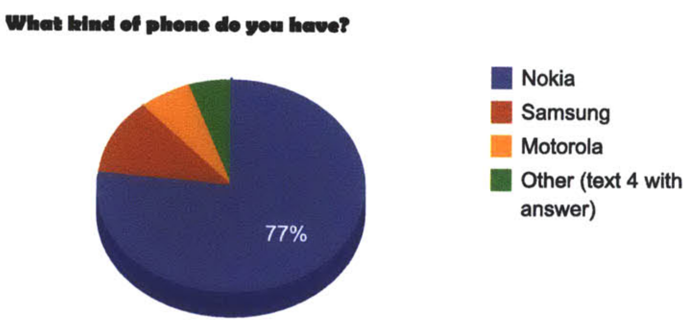
Q24 Where would you build your house?
1-"In the city" (85)
2-"Where I was born" (128)
3-"I do not know" (9)
Total: 222



Q25 Is your phone pre-paid of post-paid?
1-"Pre-paid" (177)
2-"Post-paid" (46)
Total: 223

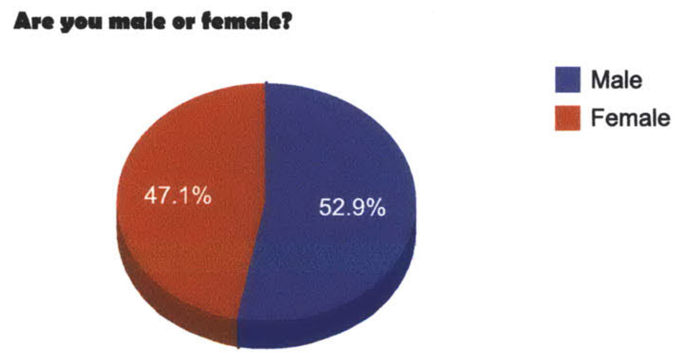


Q26 What kind of phone do you have?
1-"Nokia" (174)
2-"Samsung" (26)
3-"Motorola" (14)
4-"Other (text 4 with answer)" (12)
Total: 226

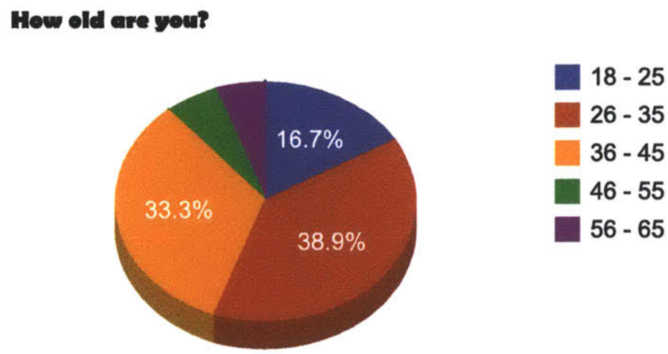


Q27 Where do you live? (Text: Town, Country)

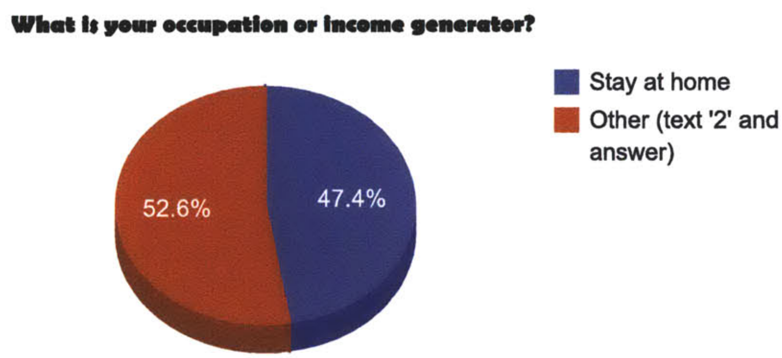
Q1 **Are you male or female?**
1-"Male" (9)
2-"Female" (8)
Total: 17



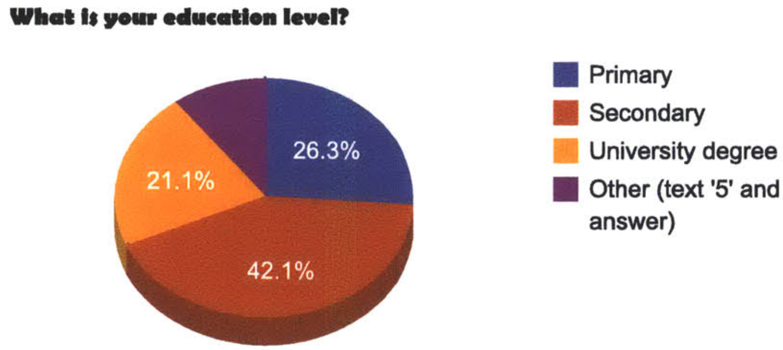
Q2 **How old are you?**
1-"18 - 25" (3)
2-"26 - 35" (7)
3-"36 - 45" (6)
4-"46 - 55" (1)
5-"56 - 65" (1)
6-"over 65" (0)
Total: 18



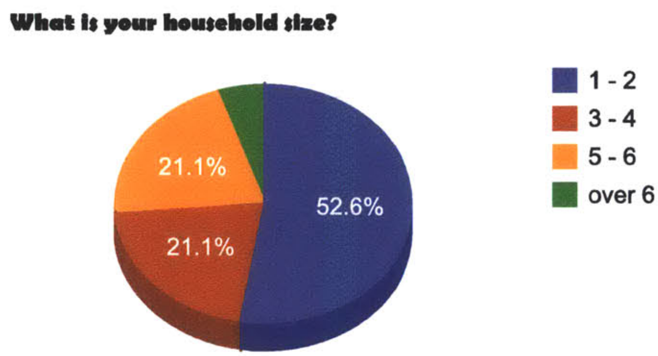
Q3 **What is your occupation or income generator?**
1-"Stay at home" (9)
2-"Other (text '2' and answer)" (10)
Total: 19



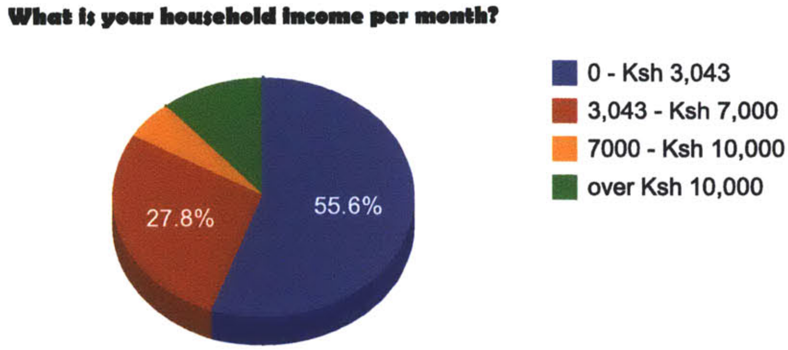
Q4 **What is your education level?**
1-"Primary " (5)
2-"Secondary" (8)
3-"University degree" (4)
4-"Community school certificate" (0)
5-"Other (text '5' and answer)" (2)
Total: 19



Q5 **What is your household size?**
1-"1 - 2" (10)
2-"3 - 4" (4)
3-"5 - 6" (4)
4-"over 6" (1)
Total: 19



Q6 **What is your household income per month?**
1-"0 - Ksh 3,043" (10)
2-"3,043 - Ksh 7,000" (5)
3-"7000 - Ksh 10,000" (1)
4-"over Ksh 10,000" (2)
Total: 18

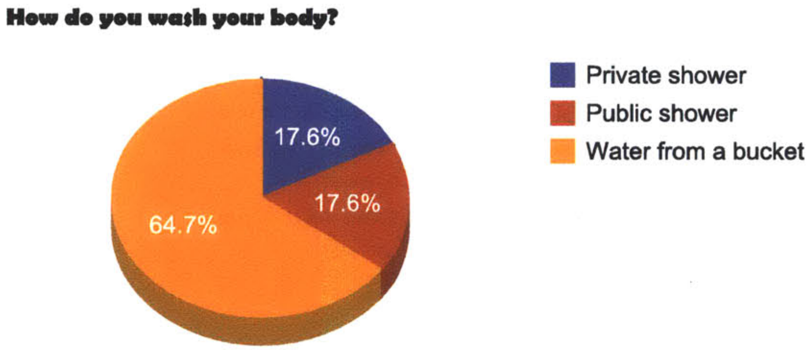


Q7 Where in Kibera do you live?
Total: 0

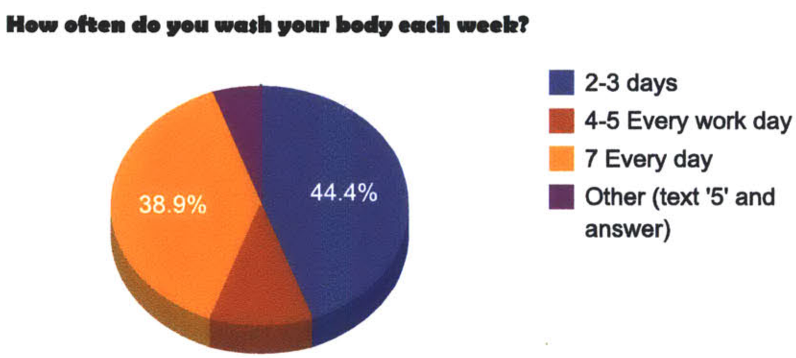
Where in Kibera do you live?

No data

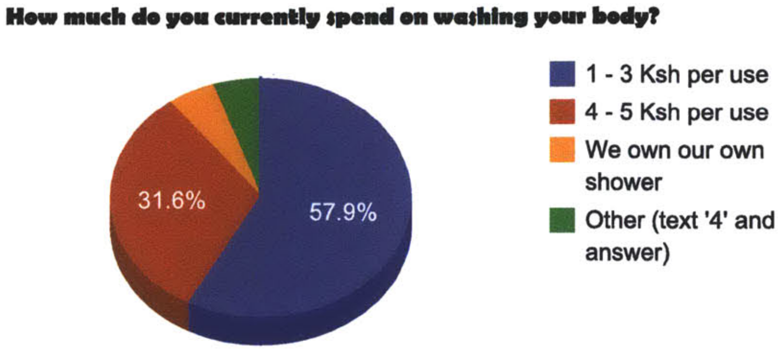
Q8 **How do you wash your body?**
1-"Private shower" (3)
2-"Public shower" (3)
3-"Water from a bucket" (11)
4-"Damp cloth" (0)
5-"Other (text '5' and answer)" (0)
Total: 17



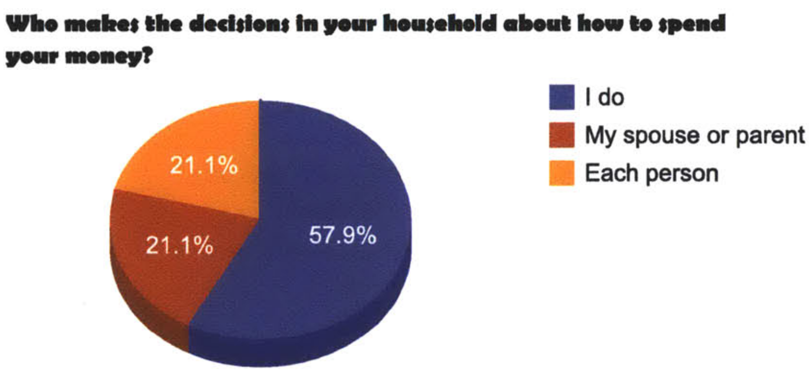
Q9 **How often do you wash your body each week?**
1-"2-3 days" (8)
2-"4-5 Every work day" (2)
3-"7 Every day" (7)
4-"On Sunday only" (0)
5-"Other (text '5' and answer)" (1)
Total: 18



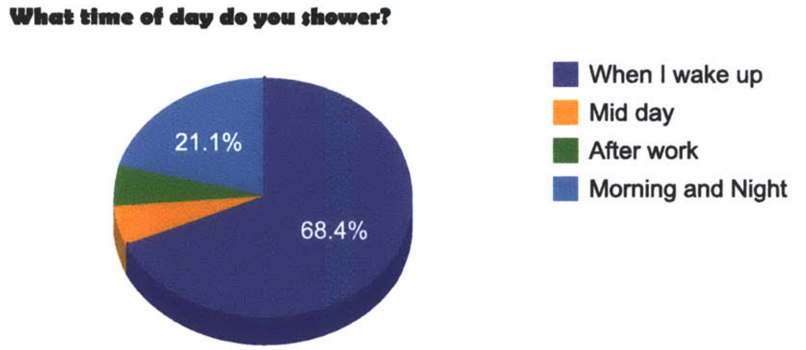
Q10 **How much do you currently spend on washing your body?**
1-"1 - 3 Ksh per use" (11)
2-"4 - 5 Ksh per use" (6)
3-"We own our own shower" (1)
4-"Other (text '4' and answer)" (1)
Total: 19



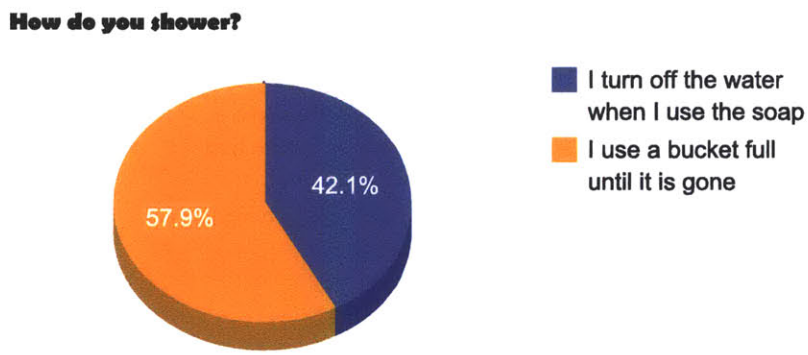
Q11 **Who makes the decisions in your household about how to spend your money?**
1-"I do" (11)
2-"My spouse or parent" (4)
3-"Each person" (4)
4-"Other (text '4' and answer)" (0)
Total: 19



Q12 **What time of day do you shower?**
1-"When I wake up" (13)
2-"Before work" (0)
3-"Mid day" (1)
4-"After work" (1)
5-"Before bed" (0)
6-"Morning and Night" (4)
Total: 19

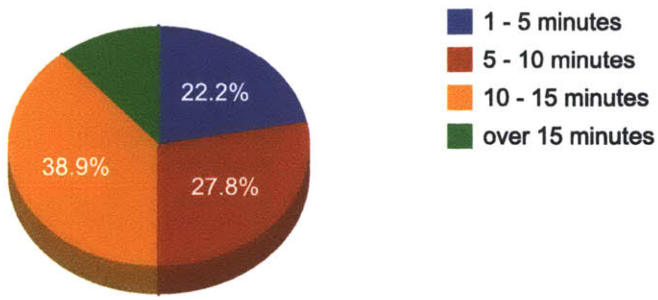


Q13 **How do you shower?**
1-"I turn off the water when I use the soap" (8)
2-"I let the water run" (0)
3-"I use a bucket full until it is gone" (11)
Total: 19



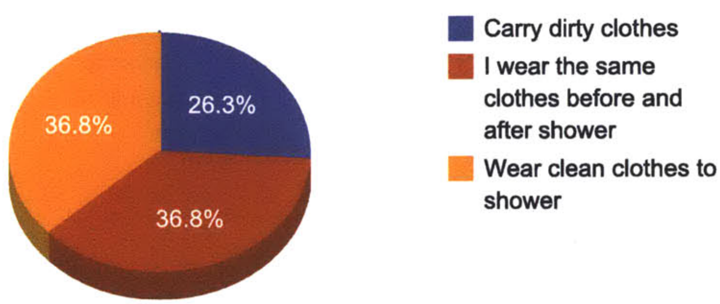
Q14 **How long does it take for you to wash your body?**
1-"1 - 5 minutes" (4)
2-"5 - 10 minutes" (5)
3-"10 - 15 minutes" (7)
4-"over 15 minutes" (2)
Total: 18

How long does it take for you to wash your body?

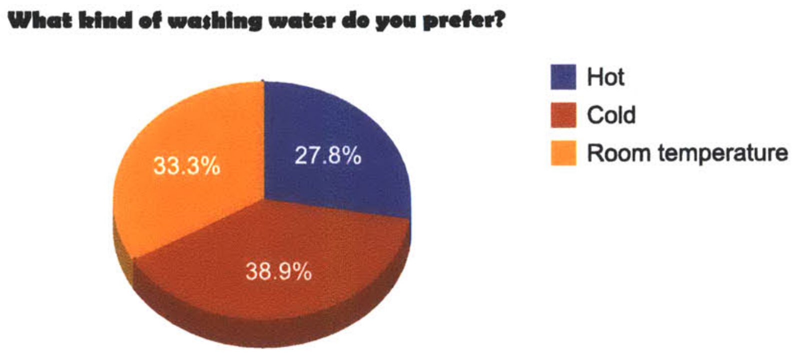


Q15 **What do you do with your clothes?**
1-"Carry dirty clothes" (5)
2-"I wear the same clothes before and after shower" (7)
3-"Wear clean clothes to shower" (7)
Total: 19

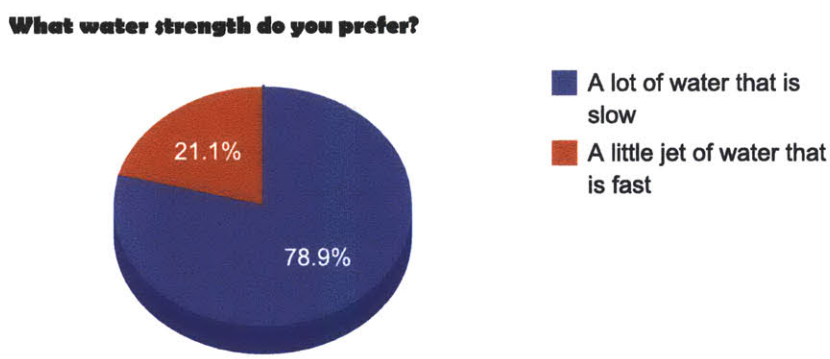
What do you do with your clothes?



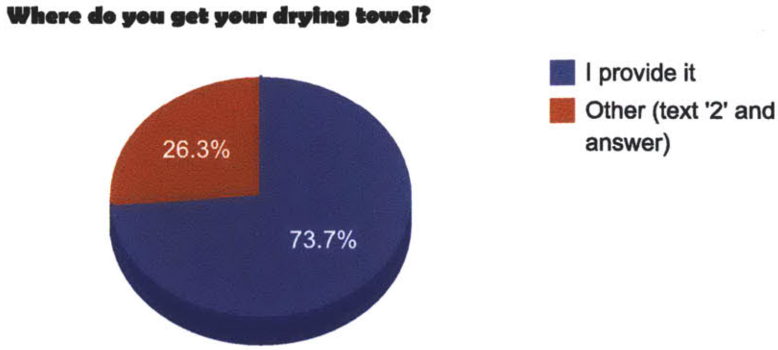
Q16 **What kind of washing water do you prefer?**
1-"Hot" (5)
2-"Cold" (7)
3-"Room temperature" (6)
Total: 18



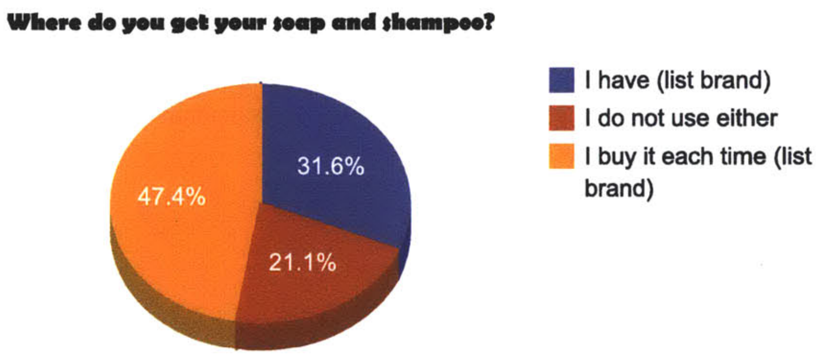
Q17 **What water strength do you prefer?**
1-"A lot of water that is slow" (15)
2-"A little jet of water that is fast" (4)
Total: 19



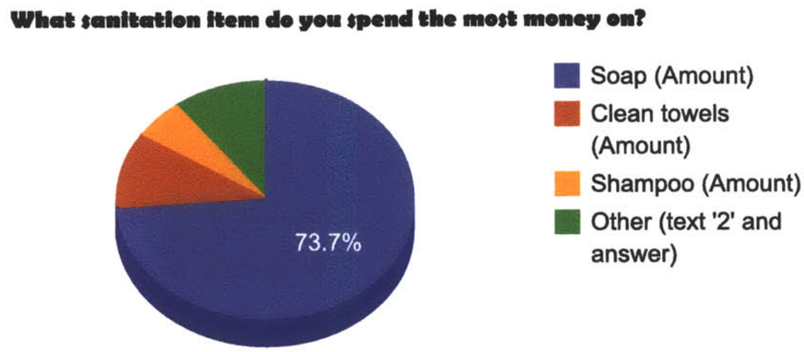
Q18 **Where do you get your drying towel?**
1-"I provide it" (14)
2-"Other (text '2' and answer)" (5)
Total: 19



Q19 **Where do you get your soap and shampoo?**
1-"I have (list brand)" (6)
2-"I do not use either" (4)
3-"I buy it each time (list brand)" (9)
Total: 19



Q20 **What sanitation item do you spend the most money on?**
1-"Soap (Amount)" (14)
2-"Clean towels (Amount)" (2)
3-"Shampoo (Amount)" (1)
4-"Other (text '2' and answer)" (2)
Total: 19



Q21 **What is the best part of current washing process?**
Total: 0

What is the best part of current washing process?

No data

Q22 **What is the worst part of current washing process?**
Total: 0

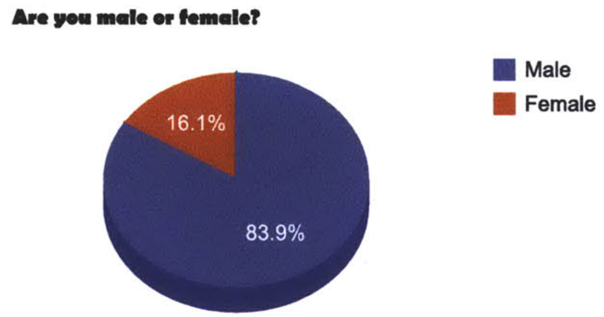
What is the worst part of current washing process?

No data

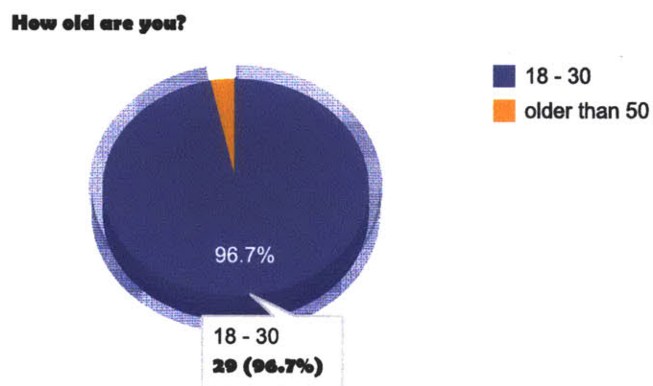
Chart Visualize

You have selected a *Chart*

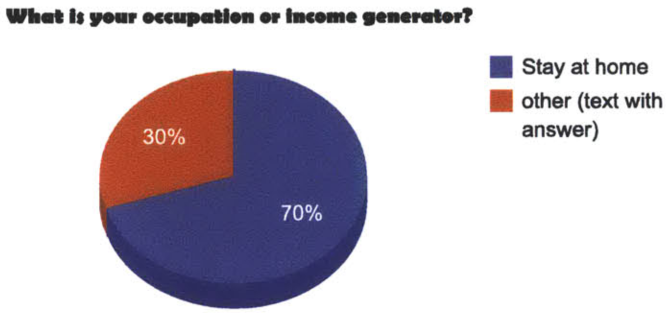
Q1 Are you male or female?
1-"Male" (26)
2-"Female" (5)
Total: 31



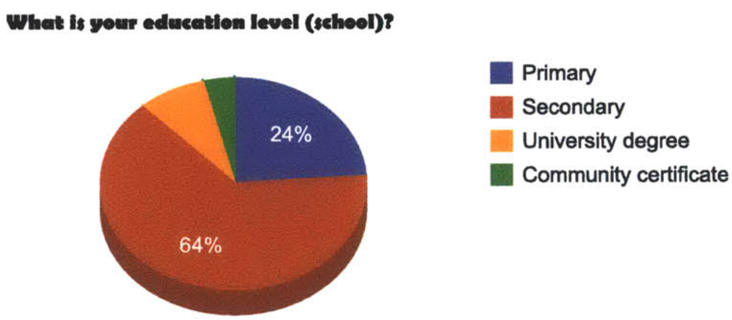
Q2 How old are you?
1-"18 - 30" (29)
2-"31 - 50" (0)
3-"older than 50" (1)
Total: 30



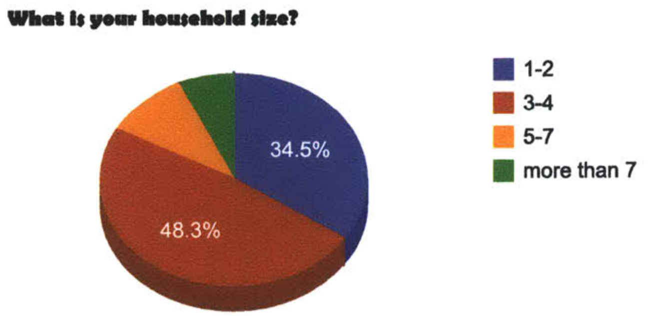
Q3 What is your occupation or income generator?
1-"Stay at home" (14)
2-"other (text with answer)" (6)
Total: 20



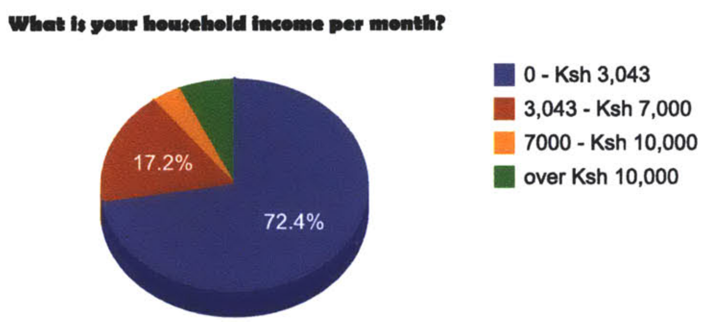
Q4 What is your education level (school)?
1-"Primary" (6)
2-"Secondary" (16)
3-"University degree" (2)
4-"Community certificate" (1)
5-"other (text your answer)" (0)
Total: 25



Q5 What is your household size?
1-"1-2" (10)
2-"3-4" (14)
3-"5-7" (3)
4-"more than 7" (2)
Total: 29



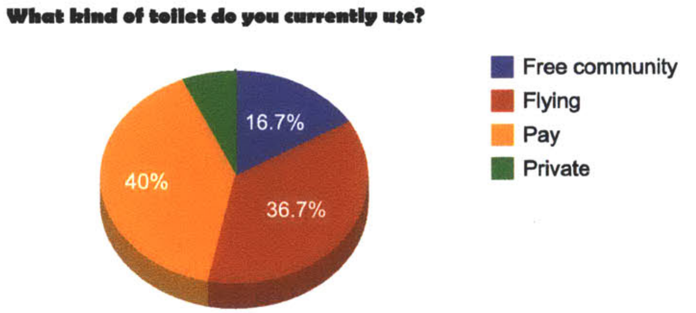
Q6 What is your household income per month?
1-"0 - Ksh 3,043" (21)
2-"3,043 - Ksh 7,000" (5)
3-"7000 - Ksh 10,000" (1)
4-"over Ksh 10,000" (2)
Total: 29



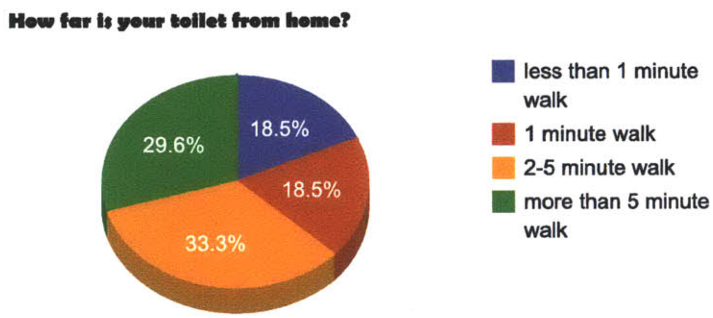
Q7 Where in Kibera do you live?
Total: 0

Q8 What kind of toilet do you currently use?
1-"Free community" (5)
2-"Flying" (11)

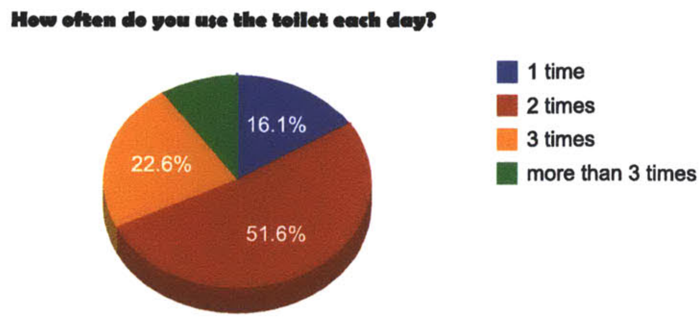
3-"Pay" (12)
4-"Private" (2)
5-"other (text your answer)" (0)
Total: 30



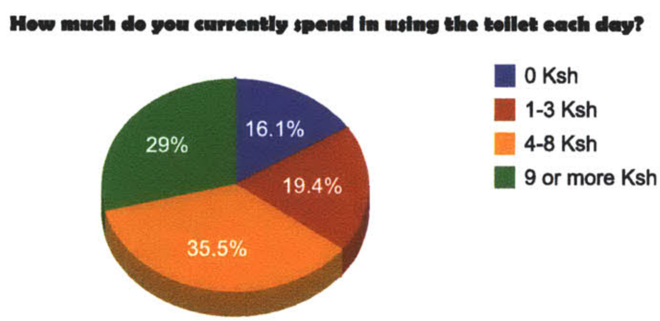
Q9 How far is your toilet from home?
1-"less than 1 minute walk" (5)
2-"1 minute walk" (5)
3-"2-5 minute walk" (9)
4-"more than 5 minute walk" (8)
Total: 27



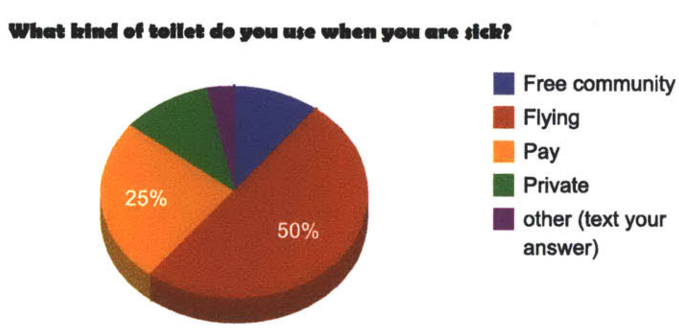
Q10 How often do you use the toilet each day?
1-"1 time" (5)
2-"2 times" (16)
3-"3 times" (7)
4-"more than 3 times" (3)
Total: 31



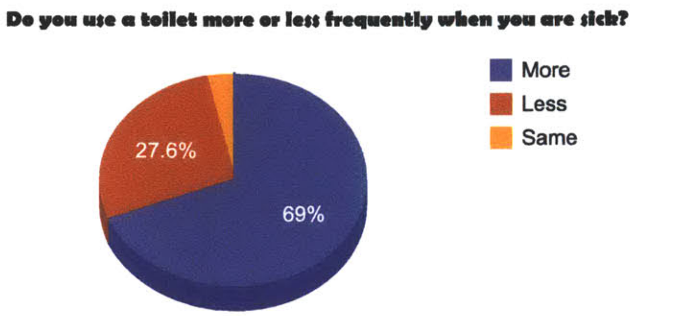
Q11 How much do you currently spend in using the toilet each day?
1-"0 Ksh" (5)
2-"1-3 Ksh" (6)
3-"4-8 Ksh" (11)
4-"9 or more Ksh" (9)
Total: 31



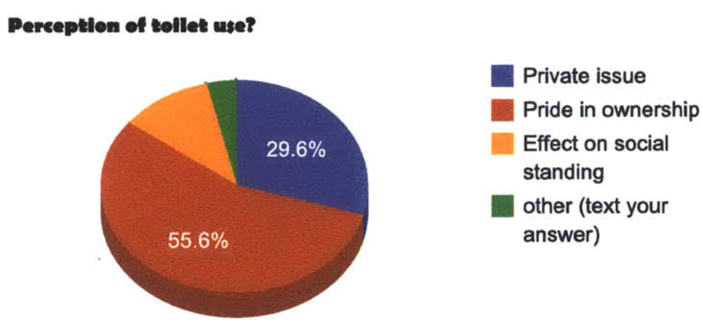
Q12 What kind of toilet do you use when you are sick?
1-"Free community" (3)
2-"Flying" (14)
3-"Pay" (7)
4-"Private" (3)
5-"other (text your answer)" (1)
Total: 28



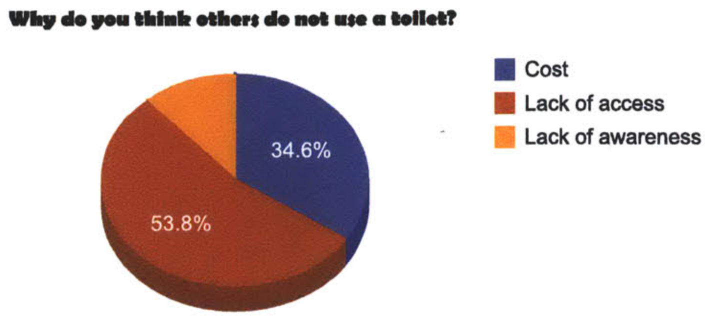
Q13 Do you use a toilet more or less frequently when you are sick?
1-"More" (20)
2-"Less" (8)
3-"Same" (1)
Total: 29



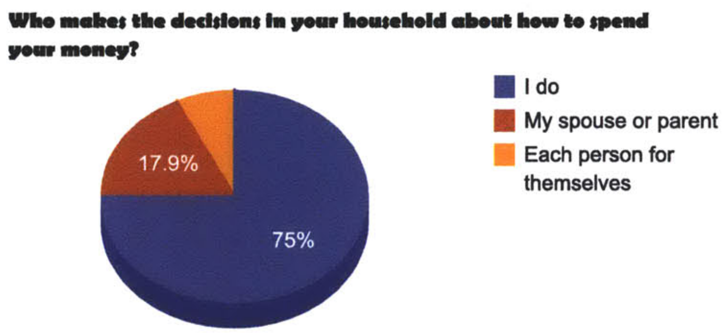
Q14 Perception of toilet use?
1-"Private issue" (8)
2-"Pride in ownership" (15)
3-"Effect on social standing" (3)
4-"other (text your answer)" (1)
Total: 27



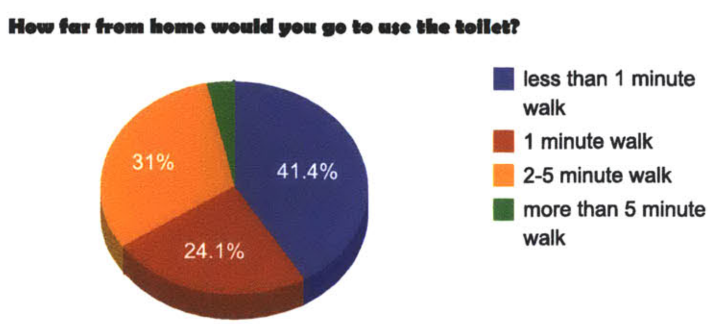
Q15 Why do you think others do not use a toilet?
1-"Cost" (9)
2-"Lack of access" (14)
3-"Lack of awareness" (3)
4-"other (text your answer)" (0)
Total: 26



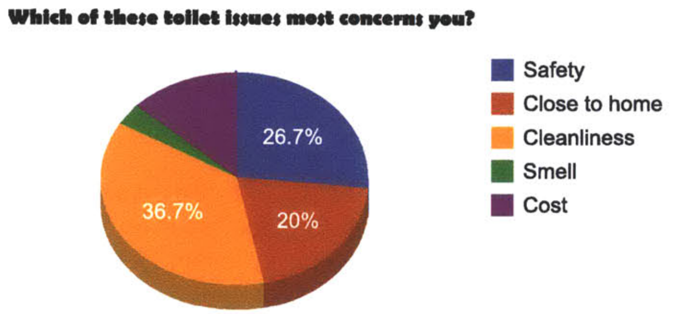
Q16 Who makes the decisions in your household about how to spend your money?
1-"I do" (21)
2-"My spouse or parent" (5)
3-"Each person for themselves" (2)
4-"other (text your answer)" (0)
Total: 28



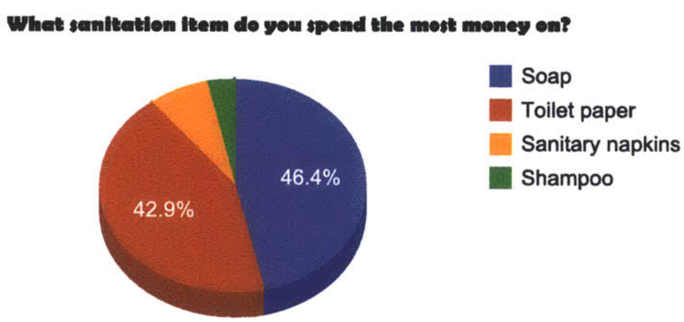
Q17 How far from home would you go to use the toilet?
1-"less than 1 minute walk" (12)
2-"1 minute walk" (7)
3-"2-5 minute walk" (9)
4-"more than 5 minute walk" (1)
Total: 29



Q18 Which of these toilet issues most concerns you?
1-"Safety" (8)
2-"Close to home" (6)
3-"Cleanliness" (11)
4-"Smell" (1)
5-"Cost" (4)
6-"Size" (0)
7-"other (text your answer)" (0)
Total: 30



Q19 What sanitation item do you spend the most money on?
1-"Soap" (13)
2-"Toilet paper" (12)
3-"Sanitary napkins" (2)
4-"Shampoo" (1)
5-"other (text your answer)" (0)
Total: 28



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