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APPLYING SYSTEMS THINKING TO DEVELOP A DESIGN SPACE AND BUSINESS STRATEGY EXPLORATION TOOL FOR TECHNOLOGY-BASED VENTURES IN DEVELOPING COMMUNITIES

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ABSTRACT

In the last five years there has been a significant rise in the number of academic and extra-curricular programs that focus on developing technology-based long-term or infrastructure projects in economically underserved communities around the world. These ventures often fail because of disconnects between the designer, the implementer, and the end-user. There is a growing trend towards curricular and extra-curricular programs and student clubs that focus on appropriate technology-based projects to address the needs of marginalized communities. It is of crucial importance to the success of the venture to identify the optimum distribution of various kinds of equity that may be shared by the communities and partnering organizations. This thesis describes the Equilibrium Spot (E-Spot) Model, a method for identifying the appropriate stakeholders within a venture and defining their roles and responsibilities towards the venture. This model is the basis for the E-Spot Canvas, a design space and business strategy exploration tool. The canvas facilitates collective thinking amongst stakeholders to match project resource requirements with time, money, sweat, and other equities that can be expended by them to sustain their project socially, economically, and environmentally.

The E-Spot Canvas serves three roles: 1) an educational tool for studying and practicing systems thinking; 2) an entrepreneurial tool for developing equitable business and implementation strategies; and 3) an ethical reflection tool for understanding motivations and incentives of various stakeholders and making decisions that optimize short-term and long-term benefit and minimize the risk for everyone involved. This thesis concerns the development and validation of the E-Spot Model and Canvas. The E-Spot Canvas is based on the systems-thinking tenets of interdependence, holism, multifinality, equifinality, differentiation, regulation, abstraction, and leverage points. I have delved into systems theory to compile and synthesize definitions of these tenets and have explained the linkages from a conceptual and practical perspective. I have piloted the E-Spot Canvas with about 80 students in various Humanitarian Engineering and Social Entrepreneurship (HESE) classes to obtain feedback and to refine it. Observations from fieldwork on HESE ventures in Kenya, Tanzania, and India have also been integrated into my entire endeavor. Three case studies have been presented in this thesis: a biogas digester, Kochia windmill project and Husk Power Systems (HPS). In addition, I have also examined application of the model to an Intelligent Street Lighting system.

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LIST OF ABBREVIATIONS

ARL	Applied Research Lab (a research unit at Penn State University)
ATSV	ARL’s Trade Space Visualizer
BOM	Bill of Materials
BOP	Base Of the Pyramid
CBO	Community-based Organization
CERS	College of Engineering Research Symposium
CYEC	Children & Youth Empowerment Center
EET	End-Equipment Team (as referenced to Texas Instruments, Inc)
E-Spot	Equilibrium Spot
FMCG	Fast Moving Consumer Goods
GPS	Global Positioning System
HESE	Humanitarian Engineering & Social Entrepreneurship
HPS	Husk Power Systems
IEG	Independent Evaluation Group
IJSLE	*International Journal for Service Learning in Engineering*
JKUAT	Jomo Kenyata University of Agricultural Technology
KDG	Kochia Development Group
KPA	Key Performance Area
LED	Light Emitting Diode
MTSO	Money, Time, Sweat, Other (as referenced to various forms of resources or equities)
NCIIA	National Collegiate Inventors and Innovators Alliance
NERC	North-American Electric Reliability Council
NGO	Non-Governmental Organization
PSU	Pennsylvania State University
QA/TQM	Quality Assurance/Total Quality Management
SEWA	Self Employed Women’s Association
UN	United Nations
UNIDO	United Nations Industrial Development Office
UoN	University of Nairobi
UTech	University of Technology, Jamaica

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Chapter 1

Introduction

1.1 Motivation

Technology ventures in developing communities often fail because of disconnects between the designer, the implementer, and the end-user. There is a growing trend towards curricular and extra-curricular programs and student clubs that focus on appropriate technology-based projects to address the needs of marginalized communities at the Base of the [socio-economic] Pyramid (BOP). Finding the optimum distribution of time, money, and sweat equity to be shared by the communities and partnering organizations can be pivotal in achieving long-term, sustainable impact for the communities. The Equilibrium Spot (E-Spot) Model seeks to identify the appropriate stakeholders within a venture and define their individual roles and the form of equity they might offer towards fulfilling the overarching objectives of the venture, while meeting their own needs. This model is the basis for the Equilibrium Spot (E-Spot) Canvas, a design space and business strategy exploration tool.

1.2 Overview of the Thesis

This thesis is comprised of seven chapters. Chapter 1 introduces the basic ideology behind the study, followed by the intellectual capital that we intend to build through this work.

Chapter 2 provides necessary background information with respect to various factors such as engineering design, end-of-life issues, failure analyses, stakeholders, economic analyses, various socio-cultural factors in society and equity matching. Another important factor that will be discussed in this chapter is the concept of Leverage Points.

Chapter 3 introduces the concept of the Equilibrium Spot (E-Spot) Model. I address the basic concept behind the model, why it was created and how it can be used for any venture. I then describe how the E-Spot Model enables stakeholders to allocate resources, split equities among them, successfully place technologies on the ground and optimize opportunities to sustain their projects socially, economically, and environmentally.

Chapter 4 begins with a brief description of the concept of the Business Model Canvas developed by Alex Osterwalder. Further, the chapter discusses further development of the E-Spot Model into the E-Spot Canvas, a design space and business strategy exploration tool. The canvas facilitates collective thinking amongst stakeholders to find the optimum distribution of time, money, and sweat equity to be shared by the communities and partnering organizations. Student teams at Penn State started using the canvas and reported that it is very helpful in developing their business strategy for projects in developing countries.

The thesis then dives into discussing various tenets of “Systems Thinking” in Chapter 5. Systems Thinking is an approach to solving complex problems by addressing every issue as a component of a larger system, rather than as an independent aspect with non-related consequences. This thesis describes a literature review of seven tenets of systems theory, viz., Interdependence, Holism, Multifinality, Equifinality, Differentiation, Regulation, and Abstraction. For each tenet, definitions are presented from various scholars and systems theorists, followed by a synthesized definition based on our own experiences. A practical application of each tenet to a social venture is discussed followed by a micro-perspective on how the E-Spot Canvas integrates that tenet and provides an opportunity to practice it for a real-world venture. Essentially, this chapter delves into systems theory to argue that the E-Spot Canvas operationalizes systems thinking to develop business strategies for social ventures.

In Chapter 6, we present a technical case study based on the E-Spot Canvas. This case study presents a retrospective view of a large scale project developed at Texas Instruments, Inc, in partnership with a foreign city government. The goal of this case study is to demonstrate that this canvas can be applied to ventures other than “social entrepreneurship” type ventures.

The final chapter provides a summary of how to use the canvas along with a brief description of the long term development goals for the E-Spot Canvas.

Chapter 2

Background Information

A growing number of educational opportunities offered at universities engage students in the development and implementation of appropriate technology-based ventures. The technology-based solutions are intended to be economically and socially sustainable. The aim is generally two-fold: to provide students with valuable educational experiences and to address the needs of marginalized communities at the so-called base of the pyramid (BOP). These endeavors are usually well meaning, creatively designed, and enthusiastically deployed; however, for many of them, the sustainable impact does not match the vision set forth at the outset. This is due, in part, to an imbalanced valuation of immediate educational experiences for students over the long-term sustainable impact for marginalized communities (Nieusma & Riley, 2010). This is an inequity that exists in many ventures, not just within academia.

For successful technology-based entrepreneurial ventures in developing communities, the implementation process is as important as the product. We believe that successful, sustainable projects are largely determined by the local people themselves, and that "outsiders" can play only a limited role. External actors, while well-intentioned, may fail to identify the most significant barriers to sustainable development. Answers for actualizing sustainable vision projects can be found by uncovering the "sticky information" related to the societal context of the problem, and acting to overcome identified impediments in a systematic fashion. Finding the optimum distribution of time, money, and sweat equity to be shared by the communities and partnering universities and organizations is critical to achieving sustainability. The search for equilibrium in this complex context necessitates a systems thinking approach.

From a macro perspective, evaluations of development efforts to assist communities in a sustainable fashion have revealed unsatisfactory results or failure. For example, in 2004, the African Development Bank judged that 78% of the funds it disbursed were for projects that were ultimately unsustainable (Poate, 2005). Similarly, the Independent Evaluation Group (IEG), the World Bank's private sector arm, examined the performance of 627 projects that were implemented between 1996 and 2006. Its findings reveal that over 40% of all projects were unsuccessful at generating positive development results, and that in Africa specifically, more than half of the investments had low development ratings (IEG, 2007). Furthermore, when assessment of such projects was broadened to encompass a time frame beyond the immediate completion of the projects, the number of favorable assessments falls considerably. In non-VC backed ventures in such contexts, the start-up failure rate is often as high as 75% (Ruhnka, Feldman, & Dean, 1992).

Against this backdrop of highly mixed results from the efforts of professionals, we place the growing number of academic programs and extra-curricular clubs that engage students in developing appropriate technology-based solutions for developing communities around the world (Agle, Mitchell, & Wood, 1997). Anecdotal stories and summaries of technology-based social ventures mirror the literature of more formal development assistance programs. Through these stories, we hear of foreigners going into communities and installing infrastructure projects, e.g., solar panels, biodiesel systems, and water treatment facilities.

From our evaluation, it appears that the following questions are often not asked: Does this project result in sustainable value for partnering communities? Is the project's sustainable value measured? Does the project lead to *self-determined* development for the community? What are the results of the project in the long term? Thus, questions arise not only with respect to the engineering aspect of such projects, but also the context of globalization, social justice, professional ethics, and cultural balances (Nieusma & Riley, 2010). A dismal track record of development efforts brings into question the ethics and sustainability of interventions by external agents (Riley, 2007).

Beyond the participation of universities and village communities, there are a number of stakeholders who play crucial roles in project sustainability. These include non-governmental organizations (NGOs), community-based organizations (CBOs), religious groups, international aid agencies, foundations, and government-sponsored development groups. These groups serve to facilitate technology transfer and provide structure and support to interventions by university groups through their experience, personal relationships, and access to information. Many NGOs that have been operating for long durations have attained the trust and confidence of community members and leaders, providing an invaluable asset. Like all who endeavor in the development field, these entities are not without shortcomings. For example, they may have unsubstantiated wariness of university participation for various reasons, including a lack of understanding of the context and scope of projects, lack of formal relationship between themselves and university groups, fear of competition, and fear of the unknown (Mehta, 2008; Bergdall, 2003).

Our understanding of how to counter the failings of past development efforts has been developed through our experiences in the Humanitarian Engineering and Social

Entrepreneurship (HESE) Program in the College of Engineering at Penn State. In this program, we define successful, sustainable projects as those largely determined by local people, with outsiders playing only a limited role (HESE, 2011). This is because external actors, while well-intentioned, may fail to understand the community dynamics and identify the most significant barriers to realizing the ventures. To mitigate this problem, students in the HESE program begin by identifying the *sticky information* that relates to the societal context of the problem in collaboration with appropriate partners to overcome impediments in a systematic fashion (Mehta, Mehta, & Colledge, 2011; Fleishman et al., 2010). For infrastructure-based projects in developing communities in particular, we have found that the implementation process is just as important as the product. As such, we focus on finding an optimal distribution of time, money, and sweat to be shared by the communities and partnering universities and organizations and have discovered it to be critical to achieving project sustainability (Mehta K. , 2008; Mehta, Mehta, & Colledge, 2011). Sustainability, as we have come to understand it, refers to the notion that a project should be technologically appropriate, environmentally benign, socially acceptable, and economically sustainable. The quest for equilibrium among these factors necessitates a participatory approach that applies the tenets of systems thinking to the development of holistic solutions (Austin et al., 2007; Stepler et al., 2010).

Over the past ten years, HESE has led several infrastructure-based social ventures in Kenya, Jamaica, El Salvador and other countries (Pennsylvania State University, 2010). The primary challenges of these projects were not on the technical engineering side, but rather with respect to the cultural, social, ethical, and business planning aspects, mostly during project implementation (Mehta, 2008; Mehta, Mehta, & Colledge, 2011). The key challenges, from most to least important, have been designing and assessing appropriate systems; ensuring equity between the stakeholders; identifying marginalized stakeholders and engaging them in the project; understanding and managing power dynamics and privilege systems within communities; identifying and incentivizing champions; public relations; and business planning with non-cash equity (Mehta, Mehta, & Colledge, 2011).

To touch on some of the challenges with these projects, in Jamaica the most significant challenge for an anaerobic digester project was the development of trust between the partnering universities, identifying specific roles and duties and following through with full participation by each. While building a bridge in El Salvador, disputes within the community as to where the bridge would be constructed and who would benefit were critical during construction. An understanding between all the stakeholders about their precise roles, duties and benefits would have facilitated a smoother implementation of the project. For a windmill power system in Kenya, ensuring equitable contributions from the various stakeholders was the major challenge (Mehta, 2008).

These examples illustrate the need for a systematic process of implementing a solution in a collaborative and harmonious manner. This process encompasses several delicate activities including community identification and partnering, building trust, establishing communication protocols, relationship building, and making decisions by consensus. The community is the core entity that must not only claim ownership of the project, but also contribute to its genesis, organization, goals, funding allocations, and business plan. People in the community must have a voice and authority on all aspects of the project. These are not merely concerns that need to be intellectually acknowledged; rather, they demand systematic, concrete steps. Preparing students to engage in such projects enriches their educational experience while simultaneously serving as the first step towards increasing the probability of success of such ventures. There is a need for a structured methodology, along with practical tools, to ensure equity among various stakeholders.

Systems thinking emerged in the twentieth century through the critique of reductionism. The basic premise behind reductionism is to break down various phenomena into their constituent parts and study the cause-and-effect relationships between those constituent parts. Thus, at its very beginning, emergence and interrelatedness were at the core of systems thinking (Flood, 2010). There is extensive documentation, both academic and industry-based, about how systems thinking works best, what its strengths are, how to connect people naturally with it, and how to get it to take hold in an organization. Expanding on various studies of these organizations, some distinctive trends emerged and over time more organizations than ever built it into their work by:

- shifting responsibility from managers and leaders solving difficult problems alone to tapping into the intelligence and experience of an entire team or community;
- pioneering ways to build communities of practice across functional boundaries that use systems thinking as the primary vehicle for meaningful conversations around ongoing and new challenges;
- pulling together new knowledge, identifying high-leverage actions and interventions, and implementing more powerful recommendations; and
- utilizing the systems archetypes to illuminate common systemic patterns in the workplace.

However, systems thinking involves more than drawing feedback loops or using the archetypes. It is about shifting how we think, communicate, and act. Unfortunately, the process of applying systems thinking is more abstract than the definition for it. As this thesis establishes, the final goal is to develop a practical tool that aids in internalizing and implementing the various tenets of systems thinking to the engineering design and implementation design process.

In the following chapters, I build upon the basic concepts that are covered in this chapter and demonstrate how the various aspects are connected to each other, and how they leverage each other towards the ultimate goal of building the E-Spot Canvas as the ultimate systems thinking implementation tool.

Chapter 3

Equilibrium Spot (E-Spot) Model: What, Why & How?

3.1 Introduction

In this chapter, we present the basic idea behind the E-Spot Model, the description of the various blocks, and a case study.[1] The first section of this chapter discusses the challenge we are trying to address from the practical, macro, and academic perspectives. The goal here is to understand and internalize answers to basic questions about what we are trying to do, why we are trying to do so, how it will make a difference, etc. Once we have defined the challenge, we will present some basic concepts and definitions, categorize different types of technology ventures, identify the ones that our model deals with, and explain the diverse, yet converging, roles of the various stakeholders. The next section discusses the concept of the two-tiered business plan as applied to infrastructure-based projects. A quick review of the Business Model Canvas methodology, a visual approach to business modeling developed by Osterwalder (2010) follows. With this as background information, we discuss the E-Spot model in detail. The last section presents a case study on the application of this model and next steps to transform this model into a design space and business strategy exploration tool.

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[1] Some of the material in this chapter is from the paper: Mehta, C., Mehta, K., & Colledge, T. (2011). "The E-Spot Model for Designing Business Strategies for Technology-based Ventures in Developing Communities." NCIIA Annual Conference.

3.2 The Challenges

3.2.1 Practical Perspective on the Challenge

The HESE initiative and program has led several technology-based social ventures over the past ten years. These projects are tightly integrated in the student's academic program by way of credit courses, independent studies, and a certificate program in (Humanitarian) Engineering and Community Engagement. Many of these projects were infrastructure based, such as:

- waste-water treatment and energy extraction system in Jamaica;
- bridge design and construction in El Salvador; and
- windmill system and business development in Kenya.

The Jamaica project was a five year effort sponsored by the U.S. Department of Agriculture from 2004–09 in collaboration with students from the University of Technology (UTech), Jamaica. The goal was to design an anaerobic digestion system, drying beds, and vegetative system to treat poultry waste, while capturing the methane by-product from the digester to use as fuel for electricity generation. The effort involved collaborative research at both universities with lab testing as well as a pilot. Final construction of the system was completed in Spring 2009. Significant challenges with this project were the development of trust between the partnering universities, identifying specific roles and duties, and following through with full participation by each.

The Salvadoran project took place in 2005 and involved the design of a bridge to allow former combatants in El Salvador's civil war to access their farmlands during the rainy season. Most were double amputees. Key design constraints were the high water table, the project site being located in an earthquake-prone region, and lack of most resources including electricity. The partnering organization was an NGO called Voices on the Border, which had been working with the community for nearly 15 years. Disputes within the community as to where the bridge would be constructed and who would benefit were critical even during construction. An understanding between all the stakeholders about their precise roles, duties, and benefits would have facilitated a smoother implementation of the project.

During the Kenya windmill project conducted from 2004–07, students from various disciplines at Penn State, Bowling Green State University, University of Nairobi, and Kochia Development Group (a community-based organization (CBO) in Kenya) collaborated to develop a robust and sustainable hybrid power system for rural communities in western Kenya. The objective was to build the system in Kenya using Kenyan resources and to set up a profit-driven business around it to ensure economic sustainability. The project culminated in July 2007 with the construction of the pilot windmill system and implementation of the preliminary business plan. Two years later, 90% of the capital costs of about US$2,000 have been recovered. Considering that the average monthly income in the area was US$10, we believe that this is a significant accomplishment. The primary challenges of this project were not on the engineering side but on the cultural, social, ethical, and business planning aspects—mostly during project implementation. Ensuring equity from and between the various stakeholders was a major objective and engaging students in making that happen was a desired outcome. We ultimately succeeded but faced many challenges and failures (Mehta, 2008). The case study in the final section of this chapter captures the essence of our approach to ensure equity.

Based on these experiences and many others, a need was recognized for the development of a structured methodology (along with practical tools) to ensure equity from and among various stakeholders involved in technology-based ventures for developing communities. The model needed to incorporate appropriate community assessment, stakeholder analysis, and social deconstruction tools, along with identification of appropriate project management alternatives and implementation strategies to assist the user in achieving sustainable outcomes to their project(s). A desired product of this effort is an overarching methodology and a set of practical tools based on rigorous validated techniques that can be used in the educational context as well as in the field. This chapter outlines such a conceptual model and seeks to find validation and collaborators to refine it and make it more usable.

3.2.2 Macro Perspective on the Challenge

The history of development efforts to assist communities in a sustainable fashion has been fraught with peril. Anecdotal stories and summaries of the sustainability of projects engaged in by university students on technology-based social ventures mirrors the literature of more formal development assistance programs. For BOP customers, the implementation process is as important as the product itself. We have observed that many NGOs and charity organizations working in developing communities give significant handouts to people. This adversely affects their work ethic and they often expect "freebies" from the venture as well. Needless to say, philanthropic models do not lead to sustainable value creation in the community. Some development efforts do not entail the necessary detailed familiarization with the host communities, nor obtain the necessary buy-in by all pertinent stakeholders, to achieve sustainability of the project. It is essential that teams develop effective strategies from conceptualization through implementation to assessment to ensure that the venture creates truly sustainable value and does no harm.

3.2.3 Academic Perspective on the Challenge

Many projects are often grounded on a personal contact or relationship of a faculty member, a student, etc., with someone in the community. Communications may occur for some period of time between these two entities, problem identification being superficially discussed, a design takes place at the university level, and then travel takes place to implement the “solution”. Appropriate community identification and partnering, trust building, communication protocols, and relationship building are all critical factors while working on projects with developing communities. The community is the core entity that must not only claim ownership of the project, but also contribute to it—its genesis, organization, goals, funding allocations, and the business plan. The community must have a voice and authority on all aspects of the project. These are not merely concerns that need to be intellectually acknowledged; rather, they demand systematic, concrete steps to achieve. They are action items. What are the structures that need to be developed and implemented to achieve these goals in a very practical manner? What rigorous methodologies can facilitate the development and implementation of projects in a sustainable, replicable, and scalable manner?

Service learning (SL) is pedagogy of teaching, learning, and reflecting that combines academic classroom curriculum with meaningful service activities. As a teaching methodology, it falls under the philosophy of experiential education. SL enriches the learning experience, teaches civic responsibility, encourages lifelong civic engagement, and strengthens communities for the common good. However, service learning does not always espouse the central tenet of reciprocity and can very easily evolve into a one-sided program that results in an unbalanced power relationship. It is critical to ensure equity in SL projects so that people in partnering communities have a sense of ownership and pride (Riley, 2007).

Many universities engage students in SL projects in the developing world. Many such programs go around the world putting up solar panels, or biodiesel systems, or water treatment facilities, etc. Do such projects result in sustainable value creation? Is that sustainable value creation measured? Does it lead to self-determined development? What are the results of such programs in the long term? Questions arise not only for the engineering aspects, but also in the context of globalization, social justice, professional ethics, and cultural balances (Nieusma & Riley, 2010). The dismal track record of development organizations brings into question the sustainability of such interventions by external agents.

3.3 Technology-based Social Entrepreneurship

The Schwab Foundation defines Social Entrepreneurship as "[It is] about applying practical, innovative, and sustainable approaches to benefit society in general, with an emphasis on those who are marginalized" (Schwab Foundation, 2010). A social venture can be considered sustainable and successful when it is technologically appropriate, environmentally benign, socially acceptable, and economically sustainable. An intimate understanding of the context is crucial to the (student) entrepreneur as it forms the basis for the effort to affect social change. Integrating social entrepreneurship into SL programs provides students with the foundation for learning in a more holistic fashion and applying systems thinking so that it leads to more sustainable impact.

Beyond the participation of the universities and the village communities, there are a number of stakeholders who play crucial roles in project sustainability. These include Non-Governmental Organizations (NGOs), Community Based Organization (CBOs), church groups, international aid agencies, foundations, and government-sponsored development groups. These groups serve to facilitate technology transfer and provide structure and support to interventions by university groups through their experience, personal relationships, and access to information. Many NGOs that have been operating for long durations have obtained the trust and confidence of community members and leaders, which is invaluable. However, we have experienced first-hand that these groups view university participation a bit warily due to numerous issues including a lack of understanding of the true context of the work, lack of sustainable relationships between themselves and university groups, fear of competition, and fear of the unknown.

3.3.1 Types of Technology Products and Projects

We distinguish technology projects into two broad categories:

1. Infrastructure: These are projects that relate to building shared physical structures like renewable energy systems or wastewater management systems, community water filtration plants, etc.
2. Durable/Long-term Usage Products: These are expensive, shared items that are used over a longer period of time by a group of people (and/or community groups). These products may be owned by individuals, but we are concerned with situations where they are beyond the means of on individuals and are owned and shared by groups of people. Large drip irrigation systems, greenhouses, sisal decorticators, and computer for internet access, would fall into this category.
3. Fast Moving Consumer Goods (FMCGs): These are consumables that are individually purchased and used up quickly. Shampoo, chocolates, cooking oil, and cellphone credit fall into this category.

The E-spot methodology is concerned with infrastructure-based and durable long-term products that are shared and involve a number of stakeholders. For such products, a “business plan” is necessary for two entities:

1. Entity that makes/manufactures the system and sells to a number of communities.
    a. Who will make the system? Who will sell it? Who is responsible for maintaining it?
    b. Where will they make the systems? Why will they make/sell/maintain the system?
    c. What are their incentives? What is their revenue stream?
2. Entity that will purchase the system and use it (collectively) in the community
    a. What is the value created for them?
    b. How will they pay for the system?
    c. How will they sustain the system and ideally scale it up as the community grows.

3.3.2 Two-tiered Business Model

Consider an engineering firm that designs and builds small-scale environmentally friendly wastewater treatment systems for use by communities that lack access to governmental wastewater management plants. The firm needs to ascertain two things: that they will have a customer base to which they will be able to sell their product and that their customers will be able to install and sustain the systems.

The engineering firm will need a business plan to define how the manufacturing and selling of the wastewater treatment systems will function. This business plan would look and function similar to a conventional business plan for a technology company. We call it a Level 1 business plan.

Since the product will be a shared resource among the group(s) (and/or organizations), the engineering firm will also need to consider models of how the end-user(s) will purchase and sustain it. For example, if a community of 15 households buys this system, how will they pay for it? Will every household pay an equal share? What should be done if a certain household does not have the required financial contribution? Through what means would such households contribute? How will the system be maintained and who will pay for that? How many families can the system service? What happens if some families leave the place, or if more families move in? Are there any non-profits or faith-based organizations (like the local church) willing to contribute a certain amount? Will the contribution be on the capital expenses or will they help maintain it? Will the new system help the local government and, in turn, the community to save on property taxes? What are the duties and expectations of all the involved stakeholders?

We refer to the answers to these questions as a Level 2 business plan. A fundamental hypothesis for this model is the criticality of balanced equity from all stakeholders, which brings with it pride and ownership in the system. The equity and ownership could also result in lower barriers for social challenges or personal vendettas to hinder optimum utilization of the product, and hence further sustainability of the project. Without a realistic Level 2 business plan, the engineering firm cannot accomplish their sales goals, which in turn imperils their Level 1 business plan.

3.4 Communities, Stakeholders, and Their Roles

In all interactions between participating entities, whether they are communities, students, or other collaborators, there needs to be a mutual exchange of value and respect. The university provides knowledge, resources, time, and credibility and, in turn, receives an opportunity for students to obtain a well-rounded global education. The local community contributes indigenous knowledge, ongoing commitment to maintain equipment, and often sweat equity, in return for the direct benefits they may accrue from the project. Collaborating universities, likewise, provide technical know-how and expertise, while obtaining educational benefits for their students. Recognizing, understanding, and anticipating the knowledge and equity exchange process, the players in it and their roles, and the pitfalls awaiting the projects due to personal idiosyncrasies, power relationships, and local political and economic struggles, are often times missing from current methodologies employed in service projects.

3.4.1 What Is a Stake? Who Is a Stakeholder? Why Are They Important?

In the simplest terms, a "stake" can be defined as a monetary or commercial interest, investment, share, or involvement in something, with hope of gain (SIL International, 1999). Any individual, organization, or group that has a direct commercial or social interest, investment, share, or involvement in a certain project or product, and hopes that, upon completion, it will provide a positive or negative benefit, becomes a stakeholder of the project. However, as soon as an entity has something to gain from a project, it is necessary that they also have something to provide to it. Stakeholders can be categorized into the following four types:

- <u>Primary Stakeholders</u>: those that are directly affected by the project/venture;
- <u>Secondary Stakeholders</u>: "intermediaries", those that are indirectly affected by the project;

- Key Stakeholders: those that have significant influence (positively or negatively) upon the operation of the project/venture. They may belong to either the primary or secondary stakeholders group; and
- Marginalized Stakeholders: those that have traditionally not been involved in the domain of the project, generally due to various social and economic reasons.

3.4.2 Convergence of Stakeholders

One key challenge with social bottom-line ventures is defining the different stakes, identifying various stakeholders, and mapping them within the right categories. There are several well-recognized methodologies of stakeholder mapping (Bourne, 2008). It is very typical for the various stakeholders to operate individually. For example, those with the money will provide the requested funds and claim that their responsibility is over, or the company/group building the system will manufacture/sell it without ensuring that there exists a sustainable model to make sure that the end user will be able to repair it upon failure.

Governmental agencies, industry, and the non-profit sector are realizing the interdependence between their missions and bottom lines and are coming together in various unusual ways (Austin et al., 2007). IBM’s workforce used to donate to Goodwill in the winter, or volunteer with the Boy Scouts, and these groups were highly appreciative of the help. However, they did not expect anything more from IBM, nor from any other business. However, today, as an organization IBM partners with the non-profit Women in Technology to co-host an engineering camp for middle-school girls and is regarded as a national champion for excellence in public education. Over the last five decades, it has been observed that in a conventional setting, corporations created economic value, while non-profit organizations created social value (Austin et al., 2007). This paradigm is changing radically.

Through various incidents, corporations have realized the importance of social responsibility to maintain a happy customer base. Organizations are going beyond talks and donations to partnering with local and international non-profit groups and communities to seek innovative and sustainable solutions to social problems. This proactive approach to addressing shared social challenges is very encouraging and can have a significant impact—as long as ventures are synergistic, well-planned, and appropriately executed.

3.5 Visual Approach to Business Planning

Business planning can be a difficult task for entrepreneurs, especially those working on social ventures in chaotic international settings. Osterwalder and Pigneur have developed a highly efficient and easy to understand business model conceptualization tool, explained in their book *Business Model Generation* (Osterwalder & Pigneur, 2010). The book proposes a single reference model and business model canvas based on various parallels drawn between other business model conceptualizations (Figure 3-1).

Figure 3-1 is an easy-to-understand visualization of a business model, its independent components and how they all fit together to develop a systematic business concept. Figure 3-2 translates the Business Model visualization into a canvas that can be used to brainstorm business concepts and strategies, which can then be developed into full business plans (Osterwalder & Pigneur, 2010). Several analogies can be drawn between the conceptualization of the E-Spot Model and that of the Business Model Canvas.

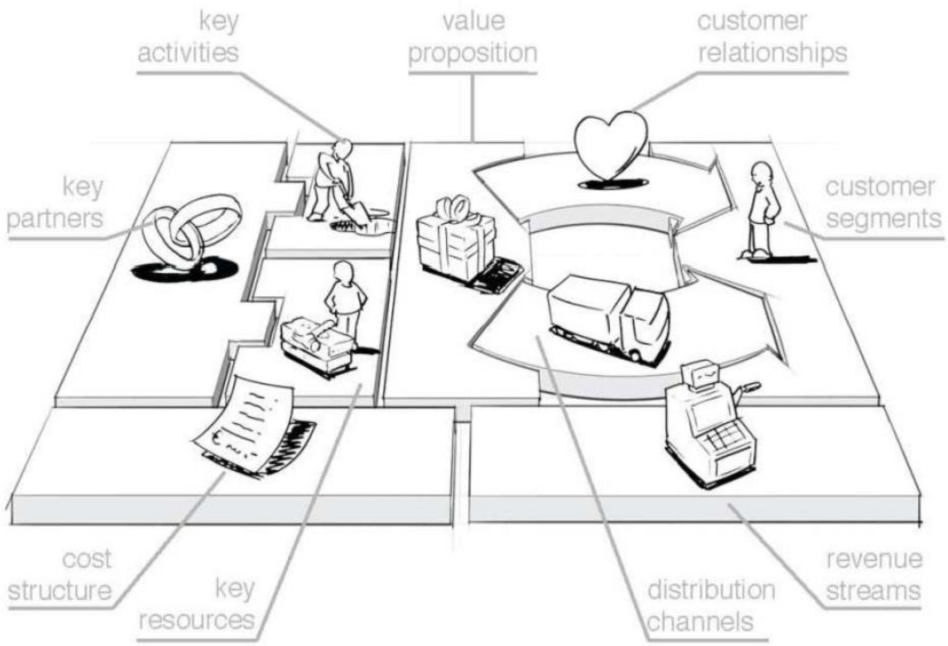

Figure 3-1: Business model visualization (from Osterwalder, 2010)

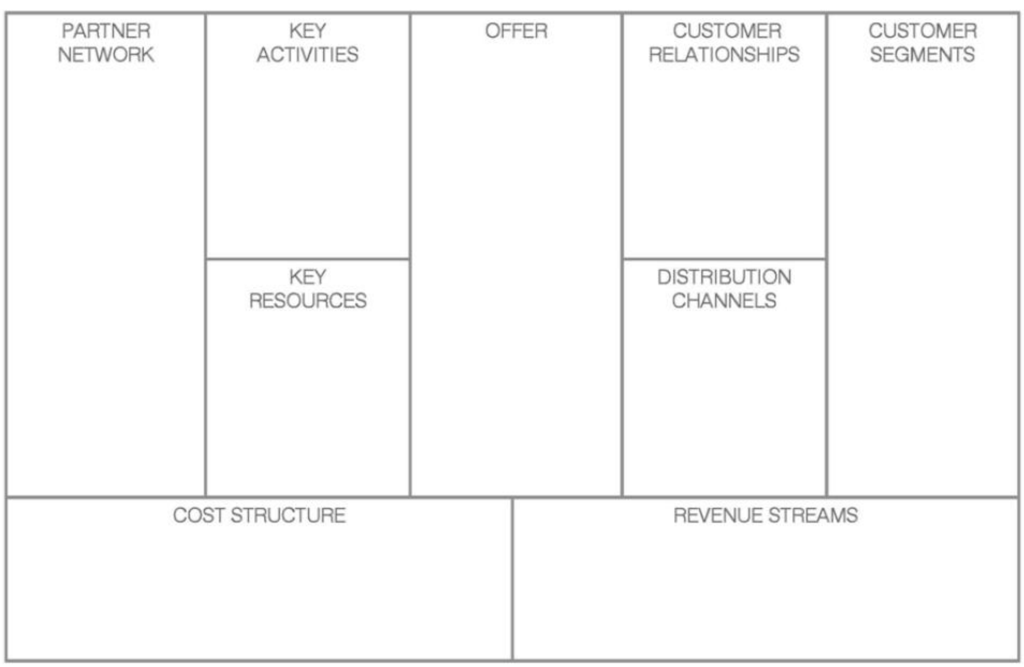

Figure 3-2: Translating the Business Model visualization into a Business Model chart (from Osterwalder, 2010)

3.5.1 E-Spot Model as a Paradigm for Business Planning for BOP

The stakeholders in technology-based social ventures in developing communities may include, but are not limited to, community members, local businesspeople, U.S. and foreign universities, U.S.-based and local funding organizations, microfinance institutions, etc. A major challenge to sustainability (and business planning) for BOP social entrepreneurship (SE) ventures is ensuring equity from and between the stakeholders (Mehta, 2008). Equity may be in the form of money, time, and sweat. Ensuring equity can be thought of as finding the sweet spot between money equity, time equity, and sweat equity "arrangements" for all the stakeholders with appropriate returns. From an academic perspective, finding innovative methods to ensure equity requires students to have a thorough understanding of the social, economic, technological, and logistical issues related to the project.

This effort is an attempt to develop a model that enables the stakeholders to allocate resources, split equities among themselves, successfully place technologies on the ground, and optimize opportunities to sustain their projects socially, economically, and environmentally. To accomplish these goals, the model hopes to incorporate the following:

- better understanding of the resources and needs of communities;
- finding organic ways for the stakeholders to contribute;
- enhancing project management by reaching consensus on the roles and responsibility of the stakeholders;
- identifying marginalized stakeholders. Who are they? Where are they? How can they be included within the system? How can the entrepreneurs and the project give them agency?

- developing a design space exploration tool to evaluate trade-offs and enable students and practitioners to optimize their business models; and
- developing metrics for the assessment of the projects, taking into consideration the different expectations for the different stakeholders.

3.6 E-Spot Model Description

The proposed model seeks to illustrate a means of finding and tracking the optimum intersection between time, money, sweat, and other equities (credibility, contact, etc.) from the various stakeholders in the venture with the backdrop of the economic and social context. This is referred to as the "Equilibrium Spot", or the E-Spot. The model is used to locate the E-Spot for the implementation, sustainability, and scalability of the venture. Figure 3-3 provides a block diagram for the E-Spot Model. The sections below describe each of the blocks of the diagram.

3.6.1 Design of Appropriate Technologies (1)

The design of the systems requires a thorough understanding of what materials are available locally, and what skills, expertise, and training capabilities exists in the community and can be accessed for the project.

3.6.2 Appropriate Technology Resource Analysis and M.T.S.O. Mapping (2 & 3)

The objective is to calculate the time, money, sweat, and other equity required for the installation, sustainability, and scalability of the appropriate technology products. The various equities are defined as:

a. <u>Money</u>: money or other material support;
b. <u>Time</u>: Time + non-labor intensive work;

c. Sweat: Time + labor-intensive work; and

d. Other equity: Knowledge, Credibility, Social Capital, Trust, etc.

3.6.3 Stakeholder Analysis (4)

The goal is to understand who the stakeholders are and what their capabilities and limitations are. We need to know the kinds of equity they can invest in the venture. In order to find these stakeholders, several methodologies have been developed. Some of them are based on:

1. the stakeholder's power to influence, the legitimacy of their relationship with the organization, and the urgency of their claim on the organization (Agle, Mitchell, & Wood, 1997);
2. value hierarchies and Key Performance Areas (KPAs) (Fletcher et al., 2003);
3. potential for threat and potential for cooperation (Savage et al., 1991); and
4. a process of identification, assessment of awareness, support, and influence leading to strategies for communication and assessing stakeholder satisfaction, and who is aware or ignorant and whether their attitude is supportive or opposing (Turner, 2002).

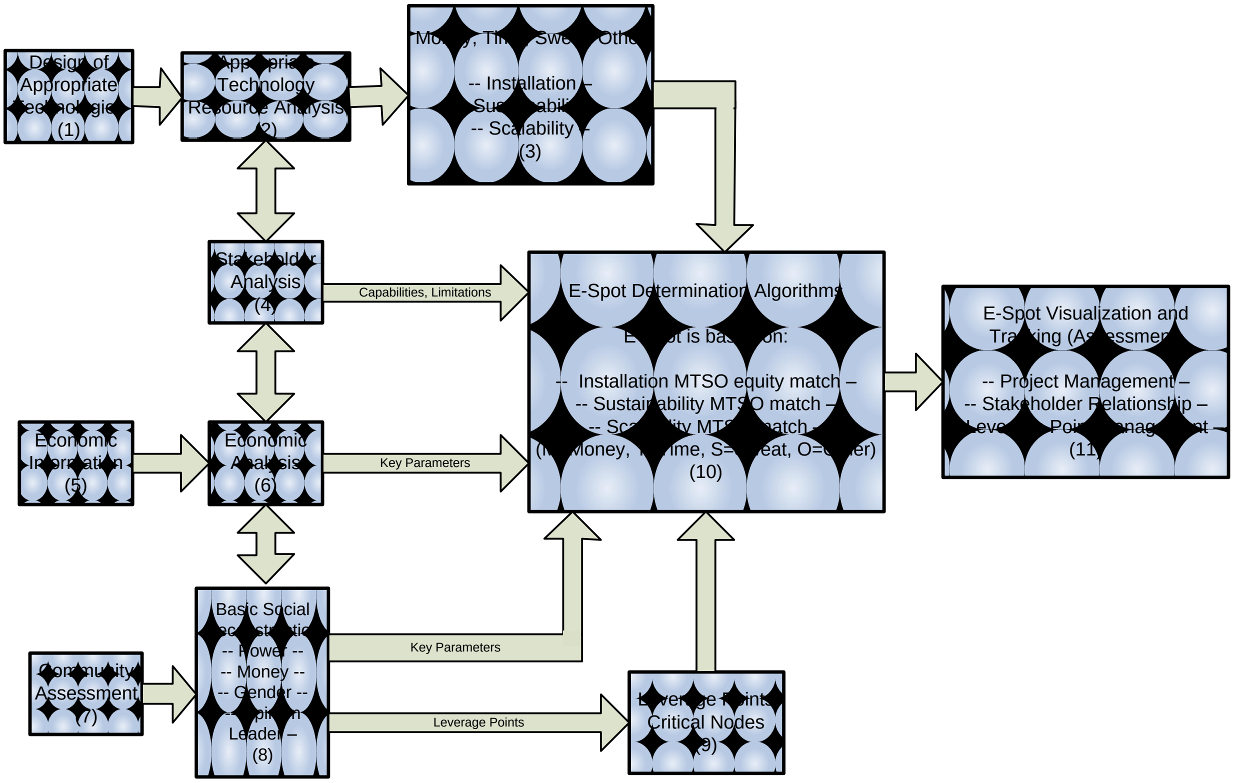

Figure 3-3: E-Spot Modeling Process Block Diagram

3.6.4 Economic Information and Analysis (5, 6)

The analyses of the local markets and trends in the region and country can be helpful. However, it is much more important to have a detailed customer profile in terms of occupation, income levels, disposable income (or other equity), lifestyle, spending habits related to the product, relevant price points, alternates to the proposed product's value proposition, etc.

3.6.5 Community Assessment and Analysis (7)

It is critical to conduct a community assessment from a social and economic perspective to better understand the community's needs, concerns, and issues. Community assessment allows the identification of problems/issues and fosters the development of better action plans around those issues. Analysis of the various groups can highlight collaborators, on-the-ground champions, and also those who can create problems. Continued community assessment is essential to track the community's needs and attempt to fulfill them. Several methods exist for community assessment and analysis: focus groups and interviews, community-wide forums, asset mapping, etc. While assessing a community, it could be helpful to collect information about the members' lifestyles, occupations, religious backgrounds, etc.

3.6.6 Social Deconstruction (8)

It is critical to deconstruct the social situations that form the foundation of the problems we are trying to address with technology solutions. Deconstruction, in this sense, refers to the idea that there are multiple ways to analyze social situations, and an understanding of this multiplicity can help expose the workings of various power relations in a given situation. Analysis of the various power relations in the communities and their interplay with the various spaces (places) can be very effective at uncovering the sticky information about the context. The power dynamics can be related to money, tribe, authority, opinion leaders, etc. Understanding the power dynamics can help us develop a business plan (equity scheme) that would create value for everyone and not reinforce traditional "winners" and "losers" or destabilize the power structure just to create new winners and losers.

3.6.7 Leverage Points and Critical Node Identification (9)

Social entrepreneurs need to understand not only immediate problems but also the larger social system and its interdependencies; this understanding allows for the introduction of new paradigms at critical leverage points that can lead to cascades of mutually-reinforcing changes that create and sustain transformed social arrangements. Deconstructing the social situations with a specific focus on the distribution of power and money, gender roles, opinion leaders, etc. will help social entrepreneurs better understand the social environment. This, in turn, will lead us to marginalized stakeholders and resources not considered earlier. It will help us identify key nodes in the network that need to be "addressed"—key players in the game that need to be strengthened or weakened. These nodes will ultimately manifest themselves as key leverage points in the equity model where an intervention is needed.

3.6.8 E-Spot Determination (10)

The E-spot determination block consists of algorithms to find the sweet spot between time, money, sweat, and other equities from various stakeholders in the venture in the backdrop of economic and social context. We call this optimized-and-stabilized point the E-Spot, in which the "E" stands for Equilibrium and Equity. To design successful business strategies, it is crucial to find E-Spots for the implementation, sustainability, and scalability of the venture. The results from the previous blocks are essential to develop the equity match and an algorithm has been summarized below. Though this may consume more time and resources, this process must be done in a participatory manner involving all the stakeholders.

1. Study the MTSO needs matrix and the stakeholder resources analysis and match the needs to the equities for Installation, Sustainability, and Scalability. The results will be in a table that shows each stakeholder group in the left-most column and what resources from the MTSO matrix they can provide.
2. Once the stakeholders versus required resources have been matched, find everything that has not been considered or paid for, either in terms of money, sweat, or time. Next, look at the Economic Analysis results and confirm that the equity matches are realistic.

3. Check if the equity matches are in-concert with the social deconstruction and leverage points blocks as well as the key findings from the stakeholder analysis and economic analysis blocks. This step may help identify additional tasks to be conducted during the implementation phase of the project.

The goal is to repeat the steps until all aspects of the MTSO equity division, stakeholder analysis, and economic analysis have been accounted for and all the stakeholders are satisfied by the equity match. The outcome of this step will be clearly defined roles, responsibilities and potential benefits for all the stakeholders. The output of this stage will table(s) similar to the one shown in Table 3-1. The E-Spot matrix will help all the stakeholders to coordinate and co-create. It is a tool to facilitate discussion, explore pathways, identify opportunities, and provide direction for social venture teams in their quest for sustainable solutions.

Table 3-1: MTSO equities allocation for installation, sustainability and scalability to the various stakeholders

Stakeholder	**Implementation**				**Sustainability**				**Scalability**			
	M	T	S	O	M	T	S	O	M	T	S	O
Community												
Local Univ.												
….												
Bank												

M = Money, T = Time, S = Sweat, O = Other (Contacts, Credibility, etc.)

3.6.9 Design Space: Exploration, Visualization, and Tracking (11)

The objective of this block is to simulate mapping of the E-Spot on highly graphic and illustrative templates that are easy to use, understand, and follow. These could be in the form of static two-dimensional scatter plots, parallel coordinate plots, or more interactive three-dimensional glyph plots.

At Penn State, the Applied Research Lab has been developing a tool called the ARL Trade Space Visualizer (Penn State, 2010). ATSV is a free Java-based, stand-alone program that allows users to either import or generate data in up to eight dimensions and identify relationships between various features across dimensions. ATSV goes beyond the conventional optimization methods and introduces users to “visual steering”, a method of leveraging the visual nature of data plots to drive the simulation model to areas of interest (Stump et al., 2009).

An example of a scatter matrix plot with 18 variables and 100 data points for each data set is given in Figure 3-4. Each block represents a 100-point dataset of one variable in reference to another. When the data are visualized in this format, it allows the user to “observe” patterns and relationships between the variables. For example, while most of the blocks have the data (red spots) scattered in a random manner, Obj3 plotted against J provides a highly linear relationship. A tool like this allows the user to define the design space better and develop focused targets for evaluation. The planned E-Spot design space exploration, visualization and tracking tool, called the E-Spot Canvas, will assist multi-sectoral partners in developing, implementing and assessing technology-based ventures.

Once the E-Spot matrices have been developed, the implementation phase can commence in a participatory manner. It is important to update the final E-Spot matrix as the equity match changes and evolves during the implementation phase. Project evaluation instruments and methodologies will ultimately be a part of the software tools and will help track the project from conceptualization to eventual tear-down. Tracking the lifecycle of the product will help design better technologies, business strategies, and effective scale-up strategies.

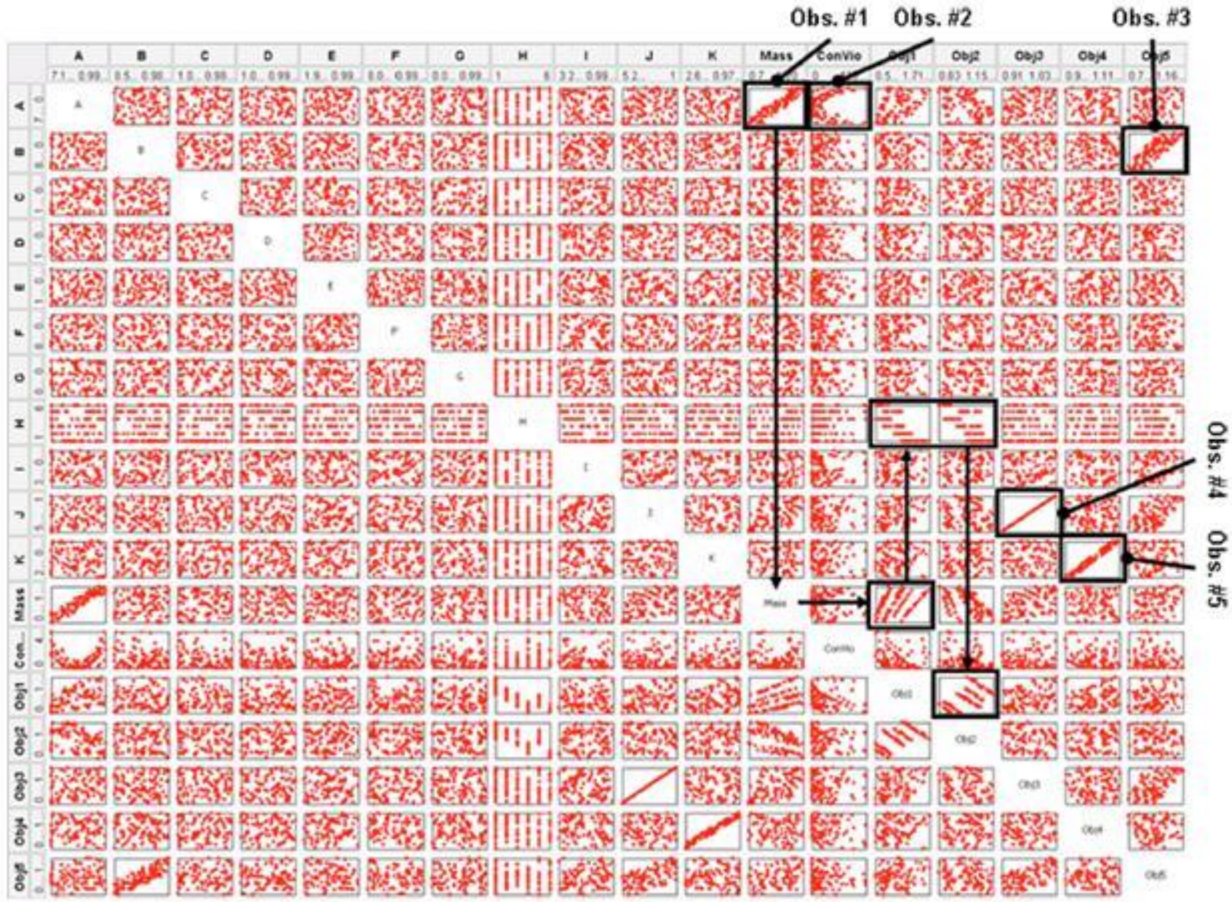

Figure 3-4: Scatter matrix plot with 18 variables, 100 data points for each for identifying patterns (from Penn State, 2010)

3.7 Case Study: Implementation Model for a Hybrid Power System Using the E-Spot Methodology

Kochia is a small village in western Kenya that lacks access to electricity. Students from various disciplines at Penn State, Bowling Green State University, University of Nairobi and Kochia Development Group (a CBO in Kenya) collaborated to develop a robust and sustainable hybrid power system for rural communities in western Kenya. The objective was to build the system in Kenya using Kenyan resources and set up a profit-driven business around it to ensure economic sustainability. This section presents a case study to illustrate how the E-Spot methodology would have been applied to develop the implementation model for this project.

The Kochia windmill project was based in Homa Bay, Kenya in 2007–08 and is currently functional as a successful enterprise for the last four years. Over these four years, more than 90% of the principal invested by the foreign sponsors has been recovered. The overall goal of the Kochia Windmill project was to set up an alternate electrical power system in a rural community called Kochia near Homa Bay. This village had never experienced an electrical system of its own but people were used to the concept of using car batteries for their small-scale power needs. Battery owners often had to walk for over 6 hours each way to the nearest charging station to get their batteries charged. It is important to note that this venture had been placed on the ground much before the conceptualization of the E-Spot Canvas. The below analysis is a post-implementation analysis and hence not as detailed.

Figure 3-5: Windmill setup at Homa Bay, Kenya

Figure 3-6: Community members learning about windmill maintenance

It is important to note here that experiences from the Kochia windmill project were crucial to the development of the canvas. The above case-study was developed retrospectively to explain the working principle of the E-Spot Model.

3.7.1 Design of Appropriate Technologies (1)

The problem we were trying to address was the lack of electricity in rural communities near Homa Bay in western Kenya. Due to exorbitant costs as well as political/administrative issues, an electric grid had not been laid out yet. Based on field research and assessment, including a data-logger that collected wind data for a year, the solution decided upon was to build a windmill in collaboration with the Kochia Development Group (KDG). An appropriate distribution system for the power generated by the windmill was also essential. We determined that the best distribution model was to have people charge batteries with the windmill. Running wires across large distances was not practical. LED-based lights were also necessary since most of the customers wanted to use the power from their batteries to light their homes. The Penn State team designed the windmill, necessary peripheral systems, and the system of operation and tested them locally. The windmill was designed for a specific price target of US$400 in steady-state manufacturing.

3.7.2 Appropriate Technology Resource Analysis (2)

This was the elaborate list of all the resources necessary for the windmill and peripheral systems. There are four major parts of the windmill:

- Foundation: This involved digging the ground, clearing it of any stray roots, rocks, etc., and laying the base for the entire windmill with concrete and steel. At the end of this stage, the construction surface for the structure was available.
- Structure: The structure was made entirely of steel. The pattern for the structure was designed to have sufficient structural integrity in order to support the blades and the wind generator.
- Wind Generator: The individual components for the wind generator were purchased in Nairobi and transported to Kochia. It included the generator, coupling for the blades, and the wiring for transferring the power to the charge controllers.
- Charge Controller: The charge controllers comprised of two 100-amp-hour battery banks that were used to store the charge from the generator on a continual basis. The individual batteries could then be charged off of these units.

Batteries and lights were the main items that needed to be brought in from outside. The lights were inexpensive in Nairobi but twice as expensive in Kochia. Hence, our team purchased them in Nairobi and sold them to customers in Homa Bay on a no-profit, no-loss basis.

3.7.3 M.T.S.O. Analysis (3)

The objective of this block is to assess the resource list developed in block 2 and categorize them into money, time, sweat, and other resources. We conducted MTSO analysis for installation and sustainability of the system. Scalability was not considered because the technology is not fundamentally scalable and the larger (Level 1) business model was to scale-up by replication.

Installation:

Money	Time	Sweat	Other
Concrete, steel	Pre-design research	Digging, steel painting, transportation of materials to site	Permissions from relevant authorities
Wind turbine and blades	Construction	Ground clearing	Land
Lights	Market analysis	Building structure	
Battery bank Individual batteries	Seeking permissions		

Sustainability:

Money	Time	Sweat	Other
Maintenance costs, supplies	Marketing	Maintenance	Bookkeeping
Repairs		Charging station operation	

3.7.4 Stakeholder Analysis (4)

The stakeholders included:

- Community: The community members were the primary stakeholders, as well as the major market segment for the system. The community consisted of sustenance farmers that lived on a daily economy with income of around US$10/month. They worked daily for 12–14 hours to ensure a daily meal (Mehta, 2008). Under these conditions it was impractical to expect any form of financial contribution from the community. Sweat (physical labor) was the most practical resource that they could provide. The Kochia Development Group agreed to build the windmill on their land as they were primary beneficiaries.

- University of Nairobi: Students at Penn State collaborated with their peers at UoN to understand the context and determine appropriate design constraints for the windmill. University of Nairobi was trusted and respected by the community members, which facilitated the entry of Penn State students into the community. UoN students and staff were the local champions capable of maintaining the system and providing engineering support if the trained community members were not able to address issues. The university also provided a bus to transport the team and equipment/supplies from Nairobi to Kochia and back. Students from UoN were also present on site during the construction phase.
- Penn State: As a university, Penn State's largest contribution was the knowledge they brought to the project. The system was designed by students at Penn State as part of various credit-bearing courses. Based on the reviewed designs, a prototype system was built at Penn State to ensure technological feasibility. Significant time was invested in ensuring support and acceptance from local chiefs, district officers, government officers, community leaders, opinion holders, and the community itself. The project lead and three students visited Kochia for 18 days to implement the system alongside teams from UoN and the community.

- NCIIA: NCIIA supports technology innovation and entrepreneurship in academia to create learning opportunities for students and successful, socially beneficial businesses (NCIIA, 2010). The windmill project was funded by a US$12,000 NCIIA Advanced E-Team grant.
- Industry: Industry becomes an important stakeholder once the technology and business models are proven as successful and profitable, thus making it attractive to industry partners interested in commercializing the system on a larger scale.

3.7.5 Economic Information and Analysis (5 & 6)

We analyzed two different aspects of the community's economic standing: the potential customer segments and the pain point for battery ownership. We identified three market segments in Kochia:

- Community Members: We conducted comprehensive surveys of 20 households to understand their financial situation and gauge their energy needs. Electricity for domestic lighting surfaced as the primary need. The average income was US$10/week and most people had a daily economy. For the few households that had the ability to save, average monthly savings were in the range of 10% to 15% of their monthly income (Mehta, 2008).
- Small Business Owners: We interviewed numerous small business owners in Kochia to understand their energy needs, e.g., a telephone operator and entertainment center owner who uses batteries to operate their telephone and music system, respectively. They would travel up to 6 km to get their battery charged. At a local bicycle repair shop, if the owner had adequate light to work after dusk, he could charge his customers a premium to get their bicycles fixed in the evening so they could report to

work the subsequent morning. A small library owner was willing to pay us US$18/month to get four hours of light (adequate for reading) every evening. There were several such small business owners who could make a higher profit by getting their batteries charged from our windmill.

- Prospective Entrepreneurs: A number of small businesses can ride on the (minuscule amount of) electricity that is provided by the windmill. Sisal decortication (for making handicrafts), handyman services, and cell-phone charging are examples of small businesses that can be started by locals. Pineapple processing and fish processing are longer term opportunities.

With respect to pain-point alleviation, we found that battery ownership was desired by the community. Based on our surveys of the small business owners, it was obvious that batteries and battery charging was an attractive market for the windmill. These batteries cost US$40 in the market. Through another set of interviews and observations, we assessed that the individuals and small-business owners could afford and were willing to pay a maximum of US$30 to own a battery.

3.7.6 Community Assessment and Social Deconstruction (7, 8, and 9)

We conducted detailed assessment of the partnering community in Kochia in conjunction with faculty and students at UoN. Some of the key people identified during this stage were:

- Village Chief of Kochia: The village chiefs for communities in Kenya hold considerable clout and it is essential to get their approval for any project/initiative you wish to undertake within their community. We sought permission from the local chief, who was extremely supportive of the project and facilitated meetings with other essential chiefs and authorities.

- Power/Opinion Leaders: These are the important people from a support perspective—they can make or break the project. We visited the pastors for all the different churches, three local chiefs, the District Officer, and District Commissioner. A neighboring community that was likely to thwart the project efforts because they did not gain anything directly was identified and meetings were held to inform them about the project.

While assessing communities, an important lesson we learned the hard way was that a community is not an independent entity that lives in a vacuum. It thrives in a living environment, surrounded by hundreds of other communities that face the same problems and issues. When a team from a foreign country comes and engages in discussions with community members, it can create a huge divide between that community and all the neighboring ones. It can cause micro-jealousy and tension between the people in the area. To avoid such situations, it is very important to arrange a social meeting with the chiefs and opinion leaders in the communities, legal office bearers, and other officials of the area and seek blessings and clearances for the project.

3.7.7 E-Spot Determination (10)

The goal is to determine how the MTSO needs identified earlier can be matched to the MTSO equity that can be expended by the various stakeholders. The matrices presented below were developed for the windmill project.

Installation:

Stakeholder	Installation			
	Money	Time	Sweat	Other
Community			Majority of Construction	Land for construction
UoN		Collaborative system design	Construction	Transportation
PSU	Funds for daily meal	System Design Project Management	Construction	Knowledge
NCIIA	Materials and supplies			Experience in starting businesses, Social Capital

As discussed earlier, the average reported per-capita income of the community was about US$10/month. It was not possible for them to have money equity in the capital cost of the project. People had to work through the day to be able to get a meal in the evening. KDG was a women's group and the old women could not assist directly with the construction. Under these circumstances, time and sweat equity from the community members were not practical, either!

We negotiated a two-point plan with the community members: 1) for every day that a community member volunteered with the construction of the system, he/she got a discount of about US$2 on the battery. The maximum discount was US$10 for working on all five "construction" days. The discount was not redeemable for cash. 2) We bought groceries for everybody (about 30 individuals) for the daily meal, which was cooked by the old women. With this equity match

- EVERYONE was actively working on the project in whatever way he or she could contribute (carrying steel, mixing concrete, babysitting, or cooking a ram).

- The people had a sense of pride and ownership of the system and realized how the money they would pay for charging the batteries would go indirectly into their own pocket because it will be used for maintaining the system and scaling up.
- We built part of our customer base for the battery charging business without giving any batteries for free (which was expected initially) or subsidizing their cost (which could have resulted in people selling the batteries for instant cash). The negotiated discount was based on our research into the pain point, i.e., the maximum amount people could afford and were willing to pay for the batteries.
- Making the batteries community-owned was initially proposed by the business student team. In that case, the batteries would certainly have been misused and mismanaged by some members (e.g., a common technique is putting an iron nail in the battery to give immediate power; it results in significant damage to the battery). Individual ownership was a better solution and the US$10 discount offered to volunteers made the batteries affordable to the community members.
- We cooked and dined together to reinforce the spirit of camaraderie and unity.

Sustainability:

Stakeholder	**Sustainability**			
	Money	Time	Sweat	Other
Community	Maintenance, Breakdown repairs from income	Local Project Management, Marketing	Maintenance, KDG routine operation	Knowledge
UoN			Breakdown repairs	Knowledge (repairs)
PSU		Expertise for complex technical problems		
NCIIA				

The pilot windmill is operated by KDG and supervised by the Board of Directors drawn from KDG, UoN, and Penn State. Deep-cycle batteries are used to store/provide power to the customers. Most customers own batteries and also have the option of renting one from KDG. KDG charges money when:

- customers get their deep-cycle battery charged from the windmill;
- customers get their cell phone charged from the solar panels; and
- customers rent charged batteries for special occasions (weddings, funerals, crusades, etc.).

The actual cost of the charging services was determined collectively after considering the competition and potential maintenance expenses. An individual nominated by KDG is responsible for charging the batteries and the day-to-day maintenance of the windmill and solar panels. This is a six-month volunteer position. As a goodwill gesture, KDG provides a deep-cycle battery and free battery recharging to the volunteer for the duration of his/her tenure. The University of Nairobi is responsible for assisting the community with repairing the windmill if the problem is beyond the scope of the community members. More complex technology problems are supposed to be reported back to Penn State. The windmill operator is required to issue receipts for all transactions. The money is deposited into a joint bank account at the Co-operative Bank of Kenya. Although anyone can deposit money into the account, multiple signatures are required to withdraw money from it. The Board of Directors looks over the bank account and approves each and every withdrawal from the account. The objective is to use these funds for maintaining the system and scaling up in the future.

3.8 Validation and Assessment of the Model

The E-Spot Model and methodology brings various stakeholders together to discuss exactly how the project is going to be designed, implemented, operated, and sustained. It seeks to find the equilibrium between the stakeholders and match their equities. Our team has applied the methodology to three other infrastructure projects where it helped develop the implementation model in conjunction with our collaborators. It provided a very clear picture of the exact roles and responsibilities of all the involved parties and the timelines for carrying out the actual tasks. The students working on the ventures also benefitted significantly from the methodology because it provided structure (and a checklist of questions) in a very chaotic and unknown environment. These were relatively simple projects that did not involve equity switches (like those explained in the Kenya windmill case study) and we will be working with partners willing to test the methodology with larger projects.

We have worked up on a case-study about the successful application of the E-Spot methodology to the design and implementation of a low-cost biogas digester in Kenya. The E-Spot methodology helped the community members understand everyone’s role and the exact tasks they had to carry out to maintain the system. While the model did not predict what would happen, it identified what needed to happen and, due to the participatory process, the stakeholders internalized why and how they had to conduct a task. The stakeholders also understood the role of the other involved parties, which resulted in an open environment with minimal community tensions.

We have also studied various design space exploration and business strategy simulation tools with the objective of developing modeling and visualization tool for this methodology. The modeling tool will provide a mechanism for stakeholders’ contributions to be entered in the model to find the deviation of the E-Spot from the intended position and thus provide a structured methodology of assessing the project itself. Model development and effectiveness will be measured by formative and summative qualitative surveys of the model users as to its appropriateness, perceived effectiveness, ease of use, and areas for improvement. Sustainability of the projects and improved student learning will be the ultimate tests of the validity of the model. In the short and medium term we will track the participation rates of stakeholders to determine if it is consistent with our model, and we will refine and adjust the model based on regular feedback from participants.

Chapter 4

Equity Matching: The E-Spot Way

4.1 Introduction

This chapter presents a design-space and business-strategy exploration tool, the E-Spot Canvas, which has been crafted to address issues of project sustainability while providing a richer learning experience to students.[2] The chapter is organized into four sections, which cover challenges of project sustainability from practical, macro, and academic perspectives; a typology of technology ventures; the E-Spot Canvas for developing implementation strategies for infrastructure-based projects; and case studies applying the canvas's methodology to real-world ventures.

The E-Spot Canvas presented in this chapter brings together distinct stakeholders and engages them in a structured process to determine how they can create sustainable value for the communities while meeting their own objectives.

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[2] A paper discussing these aspects was developed and presented at the Penn State College of Engineering Research Symposium (CERS). It has also been accepted for publication in the International Journal for Service Learning in Engineering: Humanitarian Engineering and Social Entrepreneurship (IJSLE:HESE).

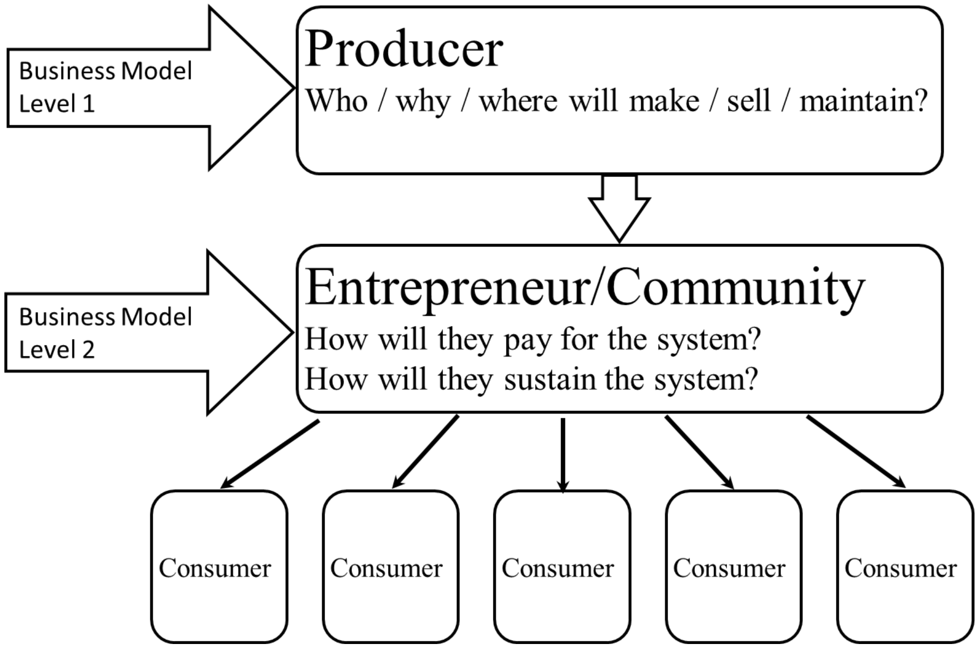

Figure 4-1: Two-level Business Plan

4.3 Visual Approach to Business Planning

Business planning can be a difficult task for entrepreneurs, especially those working on social ventures in chaotic international settings. Osterwalder and Pigneur have developed a highly efficient and easy-to-understand business model conceptualization tool (Osterwalder, et. al., 2010). The E-Spot Canvas is inspired by their Business Model Canvas and provides a structured mechanism for integrated design space, business strategy, and implementation strategy exploration. Osterwalder's canvas helps develop Level 1 business plans, whereas the E-Spot Canvas can be used to develop strategies for Level 2 business plans. The stakeholders for the Level 2 business plan may include, but are not limited to, community members, local business people, U.S. and foreign universities, U.S.-based and local funding organizations, microfinance institutions, etc. as shown in Figure 4-1 above. Stakeholder equities will be combinations of money, time, sweat, and other contributions.

Ensuring equity can be thought of as finding the sweet spot between money equity, time equity, and sweat equity "arrangements" for all the stakeholders with appropriate returns. From an academic perspective, finding innovative methods to ensure equity requires students to have a thorough understanding of the social, economic, technological, and logistical issues related to the project, and can lead to deeper learning.

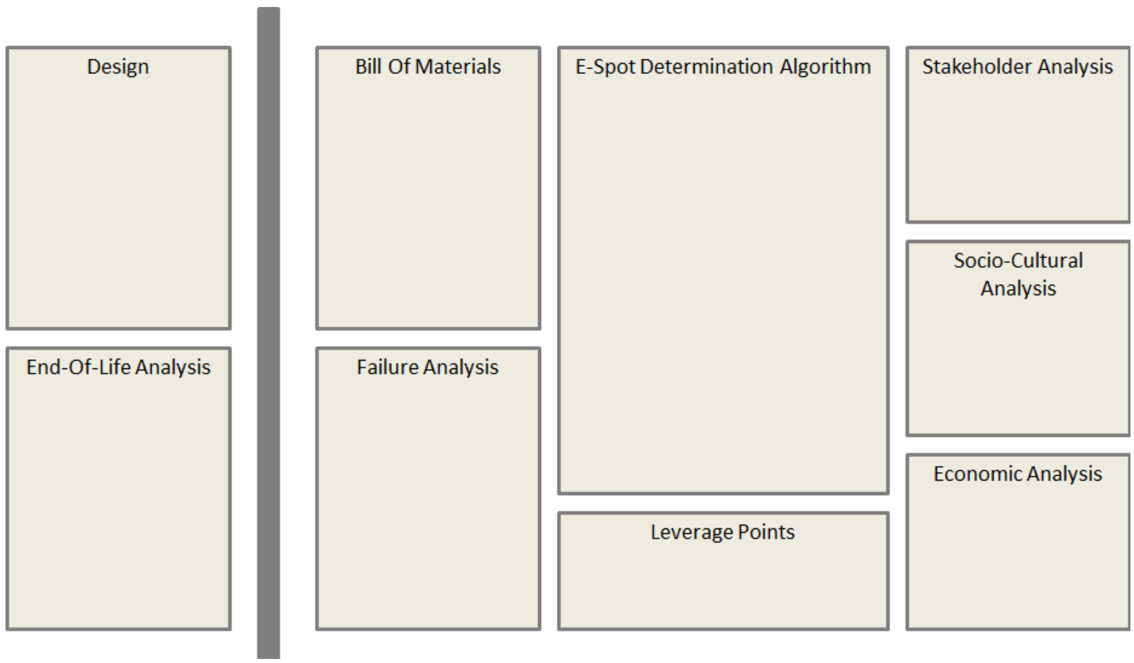

Figure 4-2: E-Spot Canvas

As shown in Figure 4-2, there are nine blocks in the E-Spot Canvas: Design, End-of-Life Analysis, Bill of Materials, Failure Analysis, Stakeholder Analysis, Socio-Cultural Analysis, Economic Analysis, Leverage Points, and E-Spot Determination Algorithm. Each of these blocks is explained in detail~~s~~ in this section. The pre-requisite for the canvas is the validated, beta-tested design and necessary community and stakeholder information. This canvas focuses on the collaborative development of the Level 2 business model only. For brevity in the sections below, the term “system” is used for an infrastructure project or a durable/long term usage product.

4.3.1 Design

The design of the system assumes consideration of locally-available materials, and the skills, expertise, and training capabilities within the community. A series of design iterations to adapt the system to local materials, as well as end-of-life considerations should be conducted in an iterative manner between the design, failure analysis, and end-of-life analysis blocks. The goal is to repeat this cycle until an optimal localized design has been obtained, and continued maintenance as well as unexpected failures have been considered and analyzed. The localization might be done for a particular community, or more likely for a region with similar resources and characteristics.

4.3.2 Bill of Materials (BOM)

The objective is to calculate the time, money, sweat, and other equities required for the installation of the system described in the design block. The Bill of Materials block on the canvas should have a table with the MTSO needs for the installation of the system. Necessary tools, as well as supplies must also be identified in this table. Resources can be grouped together as appropriate. The final outcome of this block will be a table of the form shown in Figure 4-3.

Materials	Time	Sweat	Other

Figure 4-3: MTSO block for installation BOM

4.3.3 End-Of-Life Analysis

This block will depict the plan of how every item used in the system will be recycled after its lifetime. These might be items that are discarded after a regular maintenance cycle or when the entire system is decommissioned. The overarching goal is to have a cradle-to-cradle design. Items that cannot be recycled should be identified as such, with specific instructions on how they can be discarded safely. The outcome of this block will be a table (Figure 4-4) that identifies the life expectancy of every item on the bill of materials and provides detailed guidelines and MTSO resources necessary to recycle or discard the items.

Item on BOM + Lifespan	M	T	S	O
Item 1 @ 3years				
Item 2 @ 20 years				
…				

Figure 4-4: MTSO block for End-of-life Analysis

4.3.4 Failure Analysis

This block identifies the failure modes of the system as well as regular maintenance requirements. Time, money, sweat, and other resources necessary to conduct preventive maintenance as well as those required to fix common failures are identified in this block. The failure analysis will inform the localization process as well as clarify the resources necessary for sustaining the project. The output of this block will be two tables (Figure 4-5) for routine maintenance and common failures with frequency specified for both of them.

Routine Maintenance Common Failures	M	T	S	O
RM 1 @ 3months				
…				
CF 1 @ 2 years				
…				

Figure 4-5: MTSO block for Failure Analysis

4.3.5 Stakeholder Analysis

The E-Spot methodology assumes that a community assessment to understand the community's needs, resources, and concerns was conducted and formed the basis for the design. Community assessment will help identify the primary, secondary, tertiary, and marginalized stakeholders (discussed in Section 3.4.1). Key stakeholders (amongst all categories) might have significant influence (positive or negative) on the operation of the venture and need to be identified. It is essential to identify and engage marginalized stakeholders that have not been traditionally involved in the domain of the project, generally due to various social and economic reasons. The goal is to understand who the stakeholders are and what their capabilities and limitations are. It is important to list the kinds of equities they can invest in the venture, and what their expectations are in return of their investment. For every stakeholder, summarize:

1. Who they are and what they do;
2. What their problems and needs are and how do they relate to the venture;
3. What their expectations are from the venture;
4. What equities can they offer/bring to the table; and
5. What their limitations are.

4.3.6 Socio-Cultural Analysis

The people in the community are the major stakeholders on infrastructure-based projects and a sense of ownership and pride in the project is critical to its adoption and sustainability. Community assessment from a social and economic perspective is essential to understand the community's needs, resources, and potential challenges. The assessment can highlight collaborators and on-the-ground champions, and also those who can create problems. Several methods exist for community assessment and analysis: focus groups and interviews, community-wide forums, asset mapping, etc.

The objective in this E-Spot Canvas block is to analyze the community's make-up from a social/cultural perspective—their lifestyles, occupations, historical, and religious background, etc. There should be a specific emphasis on relations between the community and the other stakeholders, and the socio-cultural status quo. Key issues include how are the people living and working day-to-day before arrival of the new system and what are their current community mores and ways of thinking. This block's outcomes are responses to questions like:

1. What social or cultural factors need to be considered for the project's implementation? Will the project disrupt the way things work right now and how can they be avoided or minimized? (e.g., potential issue for a biogas digester project could be that people are not willing to use human waste, or women will be required to feed the anaerobic digester, thus further increasing their workload.)
2. Why are the marginalized stakeholders being marginalized (in that situation)? How can the project create a win–win situation for them, too?

3. How will the community's needs evolve over time? How does that time duration work with (or against) the life of the project?
4. In the longer term, will the community formalize ownership of the project (e.g., as part of a cooperative)? What social and cultural issues need to be considered for this to happen?

The outputs of this block will be specific factors that the stakeholders think will impact the project. These factors will help identify what equities can be shared by the community members for installation or maintenance, and what socio-cultural factors need to be considered while negotiating these equities. Explicitly identifying these factors will help the stakeholders understand each other's inherent capabilities and limitations and build trust over the longer term.

4.3.7 Economic Analysis

The analyses of the local markets and trends both regionally and in the country are essential for the Level 1 Business Plans. The focus of this block is the economics of sustaining the shared resource in the community. The community is the major stakeholder. The assumption is that there will be a (possibly non-cash) revenue stream from the system that will be used by the community to maintain the system and use for other valid community issues. The most important questions are:

1. What is the cost of the competing value proposition with an emphasis on the status quo? How are people addressing the problem right now? What are its implications?
2. How much are community members willing to pay and why? A detailed community and customer profile in terms of occupations, income levels, disposable income (or

other equity), economic choices, and spending habits related to the product needs to be determined.

Other relevant economic factors include: average family income, savings ability, affordability of capital costs, ability to provide/seek informal loans, additional spending, and business growth opportunities. The outputs of this block will help identify what equities can be shared by the community members for installation or maintenance, how the supply chain and distribution channels might work, and how the community might own the project in its entirety over time and have an formal business structure (like a cooperative) to make it sustainable.

4.3.8 Leverage points

The objective of this block is to delve deeper into social dynamics to identify specific “power” relationships. The leverage points for the project can be identified through social deconstruction. Deconstruction, in this sense, refers to the idea that there are multiple ways to analyze social situations, and an understanding of this multiplicity can help expose the workings of various power relationships within communities. Understanding the power dynamics can help us develop equity schemes that create value for everyone and not reinforce traditional winners and losers or destabilize the power structure just to create new winners and losers. This analysis could be related to the distribution of power, money, gender roles, opinion leaders, tribal leaders, governmental authority figures, popular naysayers, religious leaders, etc. The leverage points will lead us to marginalized stakeholders and resources not considered earlier. It will help identify key stakeholders within the community that need to be strengthened or weakened—individuals and issues that need to be engaged in the process. The output of this block will be specific power relationships that affect the equity model.

4.3.9 E-Spot Determination

The E-Spot determination block includes algorithms to find the sweet spot between time, money, sweat, and other equities from various stakeholders against the backdrop of the economic and social context. The outcome of this final block will be two separate tables (see Figure 4-6 for installation and sustainability) that shows each stakeholder group in the left-most column and what resources will they be responsible for.

Stakeholder	Installation/Sustainability			
	M	T	S	O
Community				
Local Univ.				
….				
X Funder				

Figure 4-6: Final Equity Match Table

Developing these tables is a collaborative process that the stakeholders engage in to negotiate how their equity contributions meet the resource needs of the venture for installation and sustainability. Stakeholders start by studying the MTSO tables in the “Bill of Materials” and “Failure Analysis” blocks. These tables provide details for the resources necessary for the project’s installation and sustainability. Stakeholders identify what resources they will provide their equities towards, depending on their capabilities, limitations and expectations. This process happens with the previously identified social and economic context in mind to ensure that the equity matches are realistic.

The objective of the E-Spot Determination block is to iterate the equity allocations until all aspects of the MTSO equity match, stakeholder analysis, social, and economic assessment have been accounted for and all the stakeholders are satisfied by the equity match. The outcome of this step will be clearly defined roles, responsibilities, and potential benefits for all the stakeholders. The equity match must also be in harmony with the leverage points identified earlier. The leverage points will inform the equity match-ups and help identify additional tasks to be conducted during the implementation phase of the project to ensure project success.

The methodology employed to actually match-up the stakeholders' equities with the resource needs will vary from culture to culture and will need a facilitator who truly understands the project's needs as well as the needs and expectations of all the stakeholders. The canvas can be printed out on a large sheet of paper and then post-it notes can be used to place factors/issues/block outcomes on the canvas. The post-it notes can be moved around the canvas, combined with others, or eliminated when that particular issue has been addressed. In some ventures, there might be a need to trade the MTSO equities amongst the stakeholders. For example, a funding agency might refuse to pay for community member's wages (so that they are not seen as employers) but be willing to subsidize another object (e.g., batteries, LED lamps) which the community members would have to pay for otherwise. In this case money is being traded for sweat and the object. This equity trade, when done collaboratively, would meet the needs and expectations of the stakeholders while maintaining equity between their contributions (equities).

It is important to update the final E-Spot matrix as the equity matches change and evolves during the implementation phase. Project evaluation instruments and methodologies ultimately will be a part of the software tools and will help track the project from conceptualization to eventual decommissioning. Tracking the lifecycle of the product will help design better technologies, business strategies, and effective scale-up strategies. The next section presents several case studies on the application of the E-Spot Canvas to real ventures.

4.4 Case Study 1: Bio-Gas Digester

The first case study describes the E-Spot match-up for a biogas digester. Substantial research was conducted on this project between January and May of 2010, followed by the construction of the digester in Kenya during the Summer of 2010 (Figure 4-7). Several assumptions were made based on contextual data available from previous trips. These assumptions were validated or modified during fieldwork in Kenya. Biogas refers to a gas produced by the biological breakdown of organic matter in the absence of oxygen. It is produced by the anaerobic digestion or fermentation of biodegradable materials such as biomass, manure, sewage, municipal waste, green waste, plant material, and energy crops. Burning methane produced from biogas has been proven to reduce greenhouse gas emissions by over 13%. The many benefits that anaerobic biogas generation offers to the environment and public health coupled with the wide availability of the resources needed for its production make it an appropriate technology for implementation in developing countries. Widespread adoption of biogas generation in sub-Saharan countries like Kenya could potentially offset the use of charcoal and serve to combat deforestation and poor indoor air quality. Some of the organizations/groups involved in this case are:

- CYEC: Children and Youth Empowerment Center is a public–private organization that provides basic needs and vocational training to former street-dwelling children in Kenya;
- PSU: The Pennsylvania State University is a large public university in eastern USA;

- JKUAT: Jomo Kenyatta University of Agriculture and Technology offers accessible quality training, research, and innovation in order to produce leaders in the fields of Agriculture, Engineering, Technology, Enterprise Development, Built Environment, Health, and other Applied Sciences to suit the needs of a dynamic world; and
- UNIDO: United Nations Industrial Development Office aspires to reduce poverty through sustainable industrial development.

Figure 4-7: Field Testing of a Biogas Digester in Kenya

4.4.1 Design

The design for the biogas digester was developed based on various successful models in the market. These designs were modified based on locally available materials, the biogas requirements of the target market, and the quantity of feed for the digester. Another important consideration was the environmental and geographic factors influencing the durability and sustained operation of the system.

4.4.2 Bill of Materials

The Bill of Materials for construction of the biogas digester is presented in Table 4-1.

Table 4-1: Bill of Materials for construction of the biogas digester

Money	**Time** [Time + non-labor intensive work]	**Sweat** [Time + labor intensive work]	**Other**
Poly Tanks	Design digester and the entire system	2–3 days to dig	Transportation
PVC pipe	Survey land	Cut entry holes	PVC Maintenance
Couplers	Match w/ pipe	Saw pipes	Wood Protecting Oil
Elbows	Match w/ hose	Prep for sealant	
Gas valves	Calculate feed amount	Attach to gas tank	
Sealant		Apply to connectors	
Wood		Support structure	
Hose		Structures to valves	
G.I. Pipe		Thread pipe	
T connector		Attach to hose	

4.4.3 End of Life Analysis

End of life analysis is not covered in this case study since the market survey and project design had been conducted before the E-Spot Canvas was applied. In this capacity, the E-Spot Canvas was applied for developing a stakeholder-to-equity matching simulation.

4.4.4 Failure Analysis

The failure analysis is conducted in two phases. In phase 1, the routine maintenance for the items listed is completed, along with detailed timelines. In the second phase, any errors or failure modes brought on due to wear and tear or other natural reasons are anticipated, with approximate timelines. Table 2 outlines the failure analysis for the biogas digester.

Table 4-2: Bill of Materials for routine maintenance and specific failures of a biogas digester

Routine Maintenance	**Money**	**Time**	**Sweat**
@3 Mo		Check Sealant	
		Check Gas Valves	
@1 Yr		Check Tank	
@3 Yr	Wood Coating material		Wood Coat
@10 Yr	PVC		Change PVC

Failure Modes	**Money**	**Time**	**Sweat**
Blockage			Empty + Clean
Gas Leak	Tubing + Valves		Install new tubing, valves
Tank Leak	Sealant / New Tanks	Assess quality	Dig entire system

After obtaining the above matrices for all of the required forms of equity, installation, routine maintenance, and failure modes, the next step is to analyze the stakeholders of the project/venture.

4.4.5 Stakeholder Analysis

The goal of the Stakeholder Analysis (Table 4-3) is to assess the community and classify all involved parties into three categories: primary, secondary, and tertiary stakeholders. Among these stakeholders, identifying the marginalized stakeholders is very important.

Table 4-3: List of Stakeholders classified as Primary, Secondary or Tertiary

Primary	Secondary	Tertiary
Sustenance Farmers (M)	Large Farm Owners	PSU/JKUAT
Villagers (M)	Labor Workers (M)	CYEC (M)
CYEC Youth (M)	CBO/NGO	UNIDO
Community members	Manufacturer/ Suppliers	Community Heads

Stakeholders marked by (M) are marginalized stakeholders.

Based on our initial assumptions, we identified and validated the above stakeholders. However, we were able to classify them as primary, secondary or tertiary stakeholders only after learning more about their needs, expectations, capabilities, and limitations during fieldwork in Kenya. Furthermore, it was crucial to identify the marginalized stakeholders, the ones previously ignored by conventional systems, the economy, and society in general. Based on various analyses and social studies, we identified the marginalized stakeholders who are marked with (M) in Table 4-3 above.

4.4.6 Socio-Cultural Analysis

Community assessment from a social and economic perspective is essential to understand the community's needs, resources, and potential challenges. The objective of this analysis was to identify and highlight collaborators, on-the-ground champions, and potential troublemakers. After a thorough analysis of the community, we identified the following socio-cultural issues:

- Food scraps fed to dogs: In the current system, the residual food scraps are fed to the local dogs. If, now, the food is processed as feed into the digester, that takes away from the street dogs!
- Human waste as a feed to system: Can human waste be used as feed for the digester? It has been proven through studies that human waste is an excellent feed for a biogas digester, but do the community members feel comfortable using such fuel for cooking meals and other everyday purposes? This is a highly culture-dependent question, as is evident from the widespread use of human waste as digester feed in China.
- Environmental safety vs. putting food on the table: A major economic factor to consider in the cost of using fuel from a biogas digester versus using natural fuel such as wood from a nearby tree, which is free. While one is the more environmentally fair choice, it is also the more expensive one. The decision to use either option is a very important socio-economic factor.
- Equity in feeding reactor and sharing the biogas: In situations where a digester may be shared by more than one household, a second level of equity distribution comes into play. Which household shall be responsible for feeding the digester on what days? How much feed do they provide? How much of the gas produced do they consume? Unless there are sophisticated quantifiable methods of tracking this activity, it is difficult to ensure equal distribution.
- Biogas use: How will the biogas be used for the community and by the people? For example, is the plan to use the biogas as a cooking stove fuel? Is this desired by the people? Will they have the money to buy the new stoves?

- Cleaning “bio-digested” waste—Whose job is it anyway?: How will the community share responsibility for routine cleaning of the digester?

4.4.7 Economic Analysis

Based on the list of stakeholders, we then analyzed the economic conditions of the stakeholders in the specific geographical area with the goal of building an economic model of the target market. Some of the factors analyzed, along with the (approximate) financial amounts, were:

- Average family income: KSh 170/day (US$2.10/day)
- Cost of (purchased) coal: KSh 35/kg (US$0.45/kg) [Note: 1 kg. of coal lasts 3–4 days on average for a typical family]
- Cost of wood (lost wages): Mostly KSh 0 (Wood collection is done by women or children, who do not earn incomes directly)
- Cost of gathering digester feed—should someone be hired?: If not hired, KSh 0 (done by women and children of the house). If someone is hired, average daily salary for such jobs at KSh 100/day (US$1.25/day)

4.4.8 Leverage Points

After studying various power relationships of the community and analyzing the social dynamics, we identified the following potential leverage points:

- CYEC youth as champions—higher employment: CYEC youth stand to benefit the most from the various projects and ventures, as they can pursue them in an entrepreneurial manner.
- CYEC leaders as disseminators of information: For the marketing efforts to be successful, gaining the trust of the local people is essential. CYEC is respected by the

community and hence the management can effectively promote the biogas digester as a healthier option to charcoal.

- CYEC as a demonstration site —increased publicity: If the project is successful, the CYEC can get publicity and social capital within the local economy, and amongst the several non-profit groups visiting the center. This would help get CYEC get access to more resources and further accelerate the dissemination of this technology.
- Feeding digester in place of collecting firewood, coal: A major issue is deciding whether to collect conventional fuels or digester feed, and how that might affect the women's lives.
- Permission from town clerk: Permission from the town clerk is essential for the project to go forward.

4.4.9 E-Spot Determination

Based on the results of all the individual blocks on the canvas, we developed the following E-Spot matrix (Table 4-4) for installation of the system:

Table 4-4: E-Spot Determination Matrix for installation of a biogas digester

Stakeholders	**Installation**		
	Money	**Time**	**Sweat**
Primary Users (Community)	Supplies		
PSU Students		Tech. Design Bus. Planning	
CYEC Youth (as field experts)		Ensuring safety Community organization Access to digester feed Education	Digging, Construction of the biogas digester
Community Chiefs		Promotion of system within community	

The biogas digester venture had several inadequacies that needed to be corrected in unique and innovative ways. One major requirement was the need for physical labor at a low cost, while there was also a need for trainees who could start this as a venture. While mapping the E-Spot matrix, we realized that the older youth at the CYEC were the ideal candidates for pursuing the biogas digesters as a business endeavor. With that as the motivation, selected youth were engaged for the physical work and trained in the installation process. Similarly, another requirement was finding adequate feed for community-level digesters. It was difficult to develop a metering system whereby every member's individual usage could be monitored and billed. At the same time, a significant portion of the population could not afford such a large scale system. While developing the E-Spot matrix, the solution of smaller local digesters set up as a shared resource between 3–4 houses emerged. The ideas was that individual houses would be responsible for providing the feed and monitoring their own usage. These unique solutions emerged due to the equity mapping carried out with the E-Spot Canvas. The biogas digester was successfully deployed in Kenya in June 2010.

4.5 Case Study 2: Kochia Windmill Project

The Kochia windmill project is described in detail in Section 3.7. Here, we take a closer examination *post facto* with the E-Spot Canvas to explain the success of the system.

4.5.1 Design

The design of the Kochia Windmill in Kenya was in response to a lack of electricity in the local community. The exorbitant cost of electricity, paired with political and administrative issues, left a huge need for affordable and accessible electricity. The current solution to the problem was car batteries. For charging a car battery, a person needed to spend about 6 hours and KSh 100 (~US$1.17). For an average resident in rural Kenya earning less than US$2/day, this was worth more than half a day's salary. A weather station installed for a year revealed that the large open fields in the surrounding area were ideal windmill locations. Energy generated from the windmill would be used to charge more batteries that would operate lights and accommodate more evening and late-night activities. Increased working hours would boost productivity, generate more customer sales, earn higher profits and even increase employment. A closer examination with the E-Spot Canvas explains the success of the system.

4.5.2 Bill of Materials

The Bill of Materials for construction of the windmill is presented in Table 4-5.

Table 4-5: Bill of Materials for construction of a windmill

Materials	Time	Sweat	Other
Concrete, steel	Design research	Digging, steel painting, transportation of materials to site	Permissions from relevant authorities
Wind turbine, blades	Construction	Clearing ground	Land
Lights	Market analysis	Building structure	Long term support
Battery bank, individual batteries	Seeking permissions		Security

4.5.3 End-of-Life Analysis

End-of-life analysis is not covered in this case study since the market survey and project design had been conducted before the E-Spot canvas was applied. In this capacity, the E-Spot canvas was applied for developing a stakeholder-to-equity matching simulation.

4.5.4 Failure Analysis

Table 4-6 presents the Bill of Materials for routine maintenance and specific failures of the windmill.

Table 4-6: Bill of Materials for routine maintenance and specific failures of a windmill

Routine Maintenance	Money	Time	Sweat	Other
3 months	Greasing	Marketing	Cleaning	Bookkeeping
1 year	Repainting	Analyze tech, business model, structural analysis		Reinvesting, strategizing
5 years	Change metal structure		Rebuilding structure	
Common Failures	**Money**	**Time**	**Sweat**	**Other**
Turbine gets stuck	Greasing		Cleaning	
Batteries not charging	Charge controller	Check electrical system	Check all connections	
No profit	Marketing	New markets		

4.5.5 Stakeholder Analysis

The primary and marginalized stakeholders in this case study are the community members: subsistence farmers, local business owners, families, and the Kochia Design Group (KDG). These community members usually work 12 to 14 hours per day, and earn the equivalent of US$10 per month. Electricity is mainly used for basic needs such as lighting and business-related use. For the successful implementation of this pilot venture, neither the community nor the KDG could raise the complete funds. Community members primarily provide sweat equity for the windmill, while KDG provided the land. The secondary stakeholders in this situation included the University of Nairobi, Penn State, and National Collegiate Inventors and Innovators Alliance (NCIIA). The University of Nairobi and Penn

State both provided student and faculty with technical and business knowledge, as well as their university resources, brand recognition, and trust to the project. NCIIA was the primary funding agency. Because of the closed setting of this venture, none of the stakeholders were remote enough to be classified as tertiary stakeholders.

4.5.6 Socio–Cultural Analysis:

The main socio–cultural factors related to the windmill project were issues with the neighboring communities, political entities, and popularity of special functions. Visiting “mzungus” (white people), from the outside community are a strong influence on the traditional culture of the community. These visits breed jealousy among community members and lead to false perceptions of certain individuals getting more wealth. Political powers within the community are the village chief of Kochia, four pastors, three local chiefs, two district officers and a district commissioner. The approval of these leaders is crucial to the success of such a large project. Also, the popularity of special functions such as weddings, funerals, and religious festivals was identified as a very important part of the culture and lifestyle of the people of Homa Bay.

4.5.7 Economic Analysis

The most important customer segment for the Kochia Windmill was the business group in the community. The average salary of community members is US$10 per month, with a monthly savings of about 10–15%. Small business owners such as telephone operators and entertainment center owners earn Ksh 150 per month. The local bicycle repair shop earns Ksh 450 per month while the local library earns Ksh 1200 per month. Prospective entrepreneurs within the community work in areas such as sisal decortication, handyman services, and cell-phone charging and repair. This range of income can be considered quite stable, and similar needs exist for the majority of working community members. During the course of our analysis we also learned that a brand new battery on average cost about US$40, while the community members on average could provide US$30 toward a new battery.

4.5.8 Leverage points:

Important leverage points were determined with the power players of the community in mind:

- The Kochia Development Group;
- A well-respected NGO in Homa Bay;
- An established professor and well trusted member of the local community;
- Local pastor; and
- Local village and tribal chief.

The assistance and support of these power holders was leveraged at several instances. In one instance, the team was traveling to a neighboring village to get certain supplies; however, the road was found to be blocked by large stones and broken tree branches. Upon investigation, it was found that the road was blocked by the youth of the neighboring village, as they also wanted to work with the “white people”. A simple meeting with the village chief and an explanation of the project and future goals enlisted their full support and the roads were cleared immediately.

4.5.9 E-Spot Determination:

Table 4-7: E-Spot Determination Matrix for installation of a windmill

Stakeholder	**Installation**			
	Money	**Time**	**Sweat**	**Other**
Community			Majority of construction	Land for construction
University of Nairobi		Collaborative system design	Construction	Transportation
PSU	Funds for daily meals	System design, project management	Construction	Knowledge
NCIIA	Materials and supplies			Start-up knowledge, social capital

Table 4-8: E-Spot Determination Matrix for Sustainability of a windmill

Stakeholder	**Sustainability**			
	Money	**Time**	**Sweat**	**Other**
Community	Maintenance, Breakdown repairs from income	Local project management, Marketing	Maintenance, KDG routine operation	Knowledge
University of Nairobi			Breakdown repairs	Knowledge (Repairs)
PSU		Expertise for complex tech. problems		
NCIIA				

Significant equity disparity existed between the people in Homa Bay, Kenya. While the need for electrical power was evident and extremely crucial to its development, the village lacked economic resources. It was essential to ensure that the electricity generated through the windmill was made available to the people through non-monetary forms of payment. There should be some level of ownership from the villagers to ensure a sustained market for the power. Meanwhile, the windmill governing body needs a revenue source for maintenance and repairs during breakdowns. Based on the stakeholder and economic analyses, the design team found that batteries were the only feasible solution for distributing the power generated by the windmill. The initial plan was for the KDG to buy several batteries to be loaned out for a fee. However, the community analysis made it evident that such a system could be compromised by using nails to extend the battery's operation. This is a standard method for extending the charge in a battery at the cost of drastically reducing battery life. It was clear that every user should own their battery personally.

Based on market surveys, the team found the cost of a brand new battery to be US$40. However, information in the community analysis revealed that almost all users could spend US$30 on average for a battery. On the other side of the canvas, there was a need for physical laborers who could help with the construction of the windmill and other odd jobs. Through equity matching in the canvas, the team developed a very innovative solution. All those wanting to buy batteries were invited to help with the construction of the windmill in various forms; none were hired for monetary compensation. Those who participated were given US$2 coupons that could be reimbursed towards the purchase of a battery from the team. Several men and women participated in this scheme. Women incapable of physical labor participated in other forms such as cooking for everyone, taking care of kids while their mothers worked, etc. Construction of the windmill was finished in five days, at the end of which, the US$40 batteries were sold to the community members at US$30 in cash, and US$10 worth of coupons. The coupons could not be reimbursed in any other way. A win–win situation was created for all. This approach for providing batteries was developed and used to address the equity matching principle of the E-Spot canvas.

4.6 Case Study 3: Husk Power Systems

4.6.1 Design

Husk Power Systems (HPS) is a company based in Bihar, India that uses rice husks to generate power through gasification. Several rice millers in the state of Bihar were using the decades old technology of biomass gasification to power their mills using rice husk, largely a useless by-product of their operations with rice farming. Rice husks, which was the only large-scale bio-waste available to most rural people, was just the perfect source to implement rural electrification in this region. However, one of the biggest issues with this concept was that the prevalent rice husk-based gasifier systems ran in the “dual-fuel” mode of operation where the gas produced by the gasifiers was used in conjunction with 35–50% diesel to power the turbines. Hence, the husk-powered gasification system suited rice millers just fine by saving them 50–60% of diesel but wasn’t good enough to fit the economic model of rural electrification. A documented major issue was that rice husk biomass gasification causes significant tar generation, which leads to engine clog-ups. This issue needed to be addressed in some manner of equity distribution. As to the system specifications, the boiler and steam generation system allowed 30,000 kg/hr of 42 kg-cm steam pressure to evaporate, with a boiler efficiency of 83%. The steam turbine used as the generator had an output of 5,000 kW @ 8,000 RPM.

It is important to note that Husk Power Systems is not affiliated with the HESE program. However, we have conducted the E-Spot analysis for HPS because it is a well-known and rapidly growing social enterprise in India. Their approach to rural electrification is the subject of several case studies. Their business model and implementation strategy works with rice farmers as both clients as well as customers. They purchase husks from farmers, which makes them providers, and after converting the husks into electricity, it is sold back to them for farm operations and lighting, which makes them customers. This approach brings up several unique features related to stakeholder identification and equity allocation.

Figure 4-8: Husk-based power generation system (Image courtesy of New Ventures, http://www.new-ventures.org/files/nv/HuskPower.jpg).

4.6.2 Bill of Materials

The Bill of Materials for construction of the HPS is presented in Table 4-10.

Table 4-10: Bill of Materials for construction of a HPS

Materials	Time	Sweat	Other
Husk burning furnace	Assessment on availability of husk	Metal work	Billing systems
Generator, turbine, meters	System development based on local resource availability	Gathering husk from farmers, cleaning	
Metal for support structure	Market/customer research	Painting of all metallic parts	
Feed system for husks	Develop strategy for 'char' recycling		

4.6.3 End-of-Life Analysis

End of life analysis is not covered in this case study since the market survey and project design had been conducted before the E-Spot canvas was applied. In this capacity, the E-Spot canvas was applied for developing a stakeholder-to-equity matching simulation.

4.6.4 Failure Analysis

The Bill of Materials for routine maintenance and specific failures of a HPS is presented in Table 4-11.

Table 4-11: Bill of Materials for routine maintenance and specific failures of a HPS

Routine Maintenance	**M**	**T**	**S**	**O**
15 days			Clean furnace	
1 month	Greasing of generator	Tar disposal	Tar removal	
1 year	Paint metal structure		Rebuilding structure	
Common Failures	**M**	**T**	**S**	**O**
Turbine gets stuck	Greasing		Cleaning	Manage tar
Reduced steam	Charge controller	Furnace choke-up	Clean furnace	
No profit	Marketing	New markets		

4.6.5 Stakeholder Analysis:

An interesting facet of this system is that the primary, secondary, as well as the marginalized stakeholders are all part of the community. In this study, the customer base is 100% marginalized. Prepaid group billing is used as a way to mitigate risk associated with late or skipped payments. The Husk Power Systems (HPS) University, an educational training institute initiated by HPS, is also a major stakeholder because it is also a customer of HPS. Husk Power Systems is a unique example because the community is not only the user, but the supplier as well. Rice farmers own the largest stake in the plant by providing husks, and they become integral customers of the HPS University system. The Ministry of New & Renewable Energy subsidizes resources in order to accelerate HPS reach, and the Acumen fund also provides support for the venture. These are both considered secondary stakeholders. Tertiary stakeholders include any other smaller, external funding sources.

4.6.6 Socio-Cultural Analysis

One important aspect to consider in the implementation of an electricity generating system is the use of the resource. How will the community use the electricity, and how can productive use be fostered? There is no scientifically perfect source of energy, i.e., one that is 100% efficient or clean. The tradeoff between various energy sources must be considered in order to determine which of the options is the most efficient choice. Before HPS, over 42,000 liters (11,111 gallons) of kerosene and 18,000 liters (4,762 gallons) of diesel were used by the community on average. After implementing technology from Husk Power Systems, the monthly emission of CO_2 was reduced by 50,000 tons. This is equivalent to the CO_2 emission from over 5,000 U.S. homes over an entire year based on EPA averages.

4.6.7 Economic Analysis

Main customer segments within the community are community members and small business owners. Community members make an average income of US$30 per month and save about 10% of it every year. Small business owners work mostly within the wood and metal repair industry or within the service provision industry. Husk Power Systems charges Rs 50 (~US$1) per month for enough electricity to light one bulb. This amounts to US$900–1000 per kW in capital costs. The same amount of energy produced by coal costs twice as much, wind and hydraulic energy costs seven times as much, and solar energy costs ten times as much. Therefore, rice husks provide an alternative energy source that saves consumers half of their initial expenses. However, the calculation is not limited to savings from the cost of electricity. With the added convenience of a reliable light source, business owners are now able to work longer hours and children are able to study more conveniently. This has indirectly amounted to a much higher standard of living for several families.

4.6.8 Leverage Points

The three main power players in this example are the U.S.-educated students, the village *panch* (local governing body), and Mr. S.K. Singh, a scientist at the Ministry of New and Renewable Energy. Students educated in the U.S. are vulnerable to systems of privilege, where they can be put on a pedestal even without superior technical or social skills. The village *panch* has a very strong political influence on the decisions made by the village. Mr. Singh is a well-respected scientist who commands respect within the community. As such, his involvement with the design of the system adds credibility to the venture. The local school headmaster who was instrumental to community involvement expressed his emotions as "after sixty independent years, [the community has] found freedom from darkness." The

Samta Samidhi Foundation, which was the original name of the organization that developed the first husk power system, received twice their original investment as return on investment (ROI). After demonstrating the success from the first gasifier, the foundation built the HPS and transformed its role into that of a community-based social organization. The profit made from the first gasifier as well as a part of HPS's annual profit are used to provide free school tuition for over 250 children.

4.6.9 E-Spot Determination

Table 4-12 and 4-13 provide the E-Spot Determination Matrices for installation and sustainability, respectively, of a husk based power system.

Table 4-12: E-Spot Determination Matrix for installation of a husk based power system

Stakeholder	**Installation**			
	Money	**Time**	**Sweat**	**Other**
Community (User)			Construction	
Community (Supplier)	Husk		Rice milling	Transportation
Ministry of New & Renewable Energy	Governmental subsidies			
Acumen Fund	Materials and supplies			Start-up knowledge, social capital

Table 4-13: E-Spot Determination Matrix for sustainability of a husk based power system

Stakeholder	**Sustainability**			
	Money	**Time**	**Sweat**	**Other**
Community (User)	Usage charges, increased usage through productive use	HPS University training	Breakdown repairs	Knowledge
Community (Supplier)	Continued supply of husks			HPS University
Ministry of New & Renewable Energy	Subsidies, land grants			
Acumen Fund				Topical help

The unique aspect for Husk Power Systems is the dual responsibility and benefit from the community, both for the installation and sustainability of the system. As a general principle, HPS purchases discarded rice husks from farmers (community) at fixed prices. The farmers get money for something that used to rot by their farm and spread diseases. For HPS, these husks function as the fuel for their business. Power generated by these husks is then sold to the same and other farmers at modest rates. The company makes a decent profit, while the community (farmers) gets access to electricity several years sooner than any governmental initiative that may reach them.

During the installation phase, the community as the user provided sweat by helping with the physical construction of the system. At this time, the community as the supplier supplied sweat equity in the form of rice milling, provided transport of husks to the plant, and in return obtained direct monetary compensation. In this phase, the user's role was negligible. Suppliers had majority of the duties. In the sustainability phase, the suppliers' responsibilities thinned to continually providing husks and running the HPS University as a side venture.

Power consumers paid usage charges and learned how to use power more efficiently at the HPS University. This educational component helped quadruple power sales. At the same time, they also invested time within the HPS University significantly increasing their knowledge base. Post training, the same users also undertook repairs during breakdowns and provided specialized knowledge.

4.7 Conclusion

The E-Spot canvas is a tool that enables students and practitioners to explore design space, business strategy, and implementation strategy by bringing various stakeholders together to discuss exactly how a project will be designed, implemented, operated, and sustained. It seeks to match a project's needs with stakeholder's equities. In this chapter, we describe the application of the E-Spot canvas to three distinct infrastructure projects. In each case, the E-Spot canvas provides a clear picture of the exact roles and responsibilities of all the involved parties, and can help develop the timeline for carrying out designated tasks. The students working on the ventures also benefit from the methodology, because it provides a comprehensive and structured approach in an environment fraught with uncertainty and chaos.

Development and validation of the E-Spot canvas and methodology is a work in progress. Approximately 90 students representing twenty student teams have used the canvas for their ventures over the last year and provided us with valuable feedback. We encourage academic and non-profit partners to employ the E-Spot canvas in their own projects and help refine it while developing more case studies demonstrating its application. During the 2011–12 academic year, our team is applying the E-Spot canvas to infrastructure projects in Kenya, Tanzania, Nicaragua, and India.

Chapter 5

Systems Thinking: A New Approach to Solving Engineering Problems

5.1 Introduction

This chapter introduces the concept of Systems Thinking, its tenets, and the importance of applying systems thinking to practical, day-to-day business activities. Over the last few years, systems thinking has grown into widespread use in many large and small corporations around the world, because it offers people a way to approach complex and persistent problems more effectively. By contrast, the sense of urgency in organizations to fix problems quickly has led people to take short-sighted actions that result in unintended, adverse, and sometimes devastating effects. It is not unusual for people to acknowledge that they seem to be solving and re-solving the same problems over and over again. By bringing both the short- and long-term dimensions into the conversation, asking different kinds of questions, and making assumptions visible, we are better able to tap into the intelligence and wisdom within our organizations and, ultimately, improve the quality of our decisions and performance.

5.2 Systems Thinking & Theory

Systems thinking is the process of understanding interactions and influences between various components in a system. It may also be defined as an approach to solve complex problems, by addressing every issue as a component of a larger system, rather than as an independent aspect with non-related consequences (Ackoff, 2010). According to a study by the Waters Foundation, systems thinking is not any one thing, but a set of tools, habits and practices that help in mapping dynamic complexities (Waters Foundation, 2011), and understanding the cause–effect relationships between the various component sub-systems. A key aspect that distinguishes systems thinking is that it focuses on cyclic cause and effects, as opposed to linear cause–effect relationships (Checkland, 1981).

It is important to make a critical distinction between two often confused terms: systems thinking versus systemic thinking. While it may seem to be semantics, systems thinking advocates about real social systems that it assumes exist in the world. The corollary to that is when you implement systems thinking within a venture, the underlying assumption is the implementation of a real social venture. The second term, systemic thinking, supposes only that the social construction of the world is systemic. The implication is that a large, complex system can be broken down into smaller parts and those parts can be analyzed individually. There is a severe lack on the emphasis of interconnectedness within those parts (Flood, 2010).

For example, suppose a fire breaks out in a city; this would be called an event. If the township responds simply by putting the fire out, that would be a reaction. However, while the fire has been put out, nothing was done to minimize or prevent new fires in the future. If the township, instead, was to put out the fire and spent resources in understanding where fires break out the most within their town and what causes them, they would be studying patterns. If the township further responds by putting up more fire stations in those communities, that would be adaptation, and would be a step towards minimizing damage at future fires within that area. While that would be a positive step, it is not the ultimate outcome and hence not the ideal systemic response. In an alternate scenario, suppose the township, after putting out the fire, researches systems such as smoke detectors or fire-retarding building materials and puts into effect automated response systems, that is a highly value-creating closed-loop solution (Pegasus Communications Inc.). This solution not only aids in reducing damage caused by a fire, but actually warns before a fire starts, thereby providing an opportunity to attain a second outcome: prevention. This idea, of achieving multiple outcomes through the same inputs is called multifinality, a widely accepted tenet of systems thinking.

5.3 Defining the Tenets of Systems Thinking: Exploring the Tool-bag

In this section, we conduct a literature review of eight tenets of systems theory, viz., Interdependence, Holism, Multifinality, Equifinality, Differentiation, Regulation, Entropy and Abstraction. For each tenet, we present definitions from various well-known and established authors and systems theorists, followed by a synthesized definition developed based on our own experience. A practical application of each tenet to a commercialized social venture will be explained.

This will be followed by a detailed explanation of exactly how the various tenets fit together as a system of their own. We will provide one example of a social venture where the various tenets can be explained functioning together. In an overall perspective, however, it is crucial to internalize that, just as systems thinking does not have one standard definition, nor does any of the tenets of systems thinking. They are highly contextual and hence their definitions vary from one source to the other. It is my personal belief that on a grand scale, the several different definitions imply a similar idea, and it is this idea that I will attempt to bring forth.

5.4 Tenets of Systems Theory

5.4.1 Tenet 1: Interdependence

Senge (1990) defines interdependence as the interactive effects of tasks, goals, and feedback combinations. Saavedra, Earley, and van Dyne (1993) expand up on Senge's work and look at the dynamic relationships between all living things and the systems in which those relationships exist. At Johnson & Johnson, for example, this is operationalized by linking new employees in a manner where no employee can succeed unless all group members succeed. Group members are required to internalize that they sink or swim together for the company to succeed (Johnson, Johnson, & Holubec, 1998).

Looking at interdependence in other contexts, Colman (1998) defines interdependence in game theory as a state where all firms in a market or players in a game, though in competition, are dependent on the actions and strategies of all the other firms or players in that market or game. He says that when players are interdependent, the moves of one will have ramifications for all other players in that game. Similarly, Mackey and Santillán (2005) suggested that biological interdependence is the idea that everything in nature is connected to everything else; what happens to one plant or animal also affects other plants and animals.

We define interdependence as the mutually beneficial and reciprocal relationship between systems, aimed at satisfying the needs for development, co-creation, and resource optimization to achieve relational integrity within a larger system, of which every small individual system is a sub-system. Simplistically, interdependence means that all systems are dependent on other systems or sub-systems for successfully meeting their responsibilities.

These responsibilities and principles may be physical, emotional, financial, social, moral, or corporate.

Relevance to Design & Business Strategy for Social Ventures

For example, let us consider three individual systems: the internet, donating money in return for social goodwill, and seeking seed capital from a venture capitalist. These systems exist and sustainably survive within the global marketplace. However, from Kiva.org's perspective, these are highly interdependent sub-systems that help sustain Kiva's business model, in which an individual can donate money to an entrepreneurial venture in a developing country via the internet. In this case, these otherwise individually surviving systems are mutually dependent on each other to satisfy Kiva's needs for optimizing every donation so as to provide seed funding to promising ventures in their target markets.

5.4.2 Tenet 2: Holism

One of the first published works on Systems Theory by von Bertalanffy (1950) states that parts are interrelated and influence each other with the end result being a whole organism that exhibits emergence. In 1971, von Bertalanffy modified his definition to say that holism is the idea that all the properties of a given system, whether physical, biological, chemical, social, economic, mental, or linguistic, cannot be determined or explained by its component parts alone. Instead, the system as a whole determines in an important way how the parts behave (von Bertalanffy, 1971).

Flake (2002) suggests that holism is the idea that "the whole is greater than the sum of the parts." Holism is credible on the basis of emergence alone, since reductionism and bottom-up descriptions of nature often fail to predict complex higher-level patterns (Flake, 2002). Applying Flake's definition to action research, Flood (2010) defines holism as an emergent property of a whole, arising when a phenomenon cannot be fully comprehended only in terms of its constituent parts.

Looking at holism in other contexts, Eller (2009) defines holism as a part of the "anthropological perspective" that involves consideration of a certain aspect of a culture in relation to other aspects of that culture, and to the society where the culture is practised, as a whole. In alternative medical sciences, holism is seen as an alternative (and also controversial) treatment system that focuses on the whole person rather than on specific diseases or disorders, and considers physical, emotional, social, environmental, and spiritual factors. Pain in the stomach may be diagnosed as liver inflammation by performing acupuncture along the foot of the left leg. In this case, while the left foot and liver are independent biological systems, they are part of the human whole, and are connected through nerve centers within the brain (Berliner & Salmon, 1980).

In general, there are two aspects to holism:

- the parts of any large system can only exist and be understood in their relation to the whole and
- the whole is always greater than the sum of its individual parts.

Relevance to Design & Business Strategy for Social Ventures

Looking at Kiva.org, it has been demonstrated earlier how Kiva relies on three independent yet interdependent systems. From a holistic viewpoint,

- Kiva as a larger system can only exist and be understood by understanding its sub-systems, viz., internet, donations for social goodwill, and seeking seed capital. Further, it must be assessed exactly how these three independent systems will function in relation to each other for Kiva to meet its objectives; and

- Kiva, within its context, will always provide a higher value proposition than its sub-systems operating individually.

Donation-based models of community service have failed over and over again. In such models, individuals or organizations raise funds in the western world through donations and grants, and then install developmental infrastructure such as windmills or water treatment plants in rural areas of developing countries. The rural communities are often ignored during the decision process. While attempts may be made to understand the individual components of the system, they are not analyzed in relation to each other and this lack of holistic approach causes the project to fail (Haimes, 1992).

5.4.3 Tenet 3: MultiFinality

von Bertalanffy (1971) states that multifinality is defined as attaining varied alternative objectives from the same inputs, all systems remaining constant. Cicchetti and Rogosch (1996) expand on the concept of attaining varied objectives and define multifinality as divergence: several outcomes from parameters in an interconnected hierarchical system. Luyten et al. (2008) define multifinality as similar developmental factor leading to dissimilar outcomes.

Looking at the above definitions in the context of epidemiology of childhood trauma, it has been demonstrated through several research studies that children exposed to similar childhood trauma may manifest multifinality—similar stressors could be associated with distinctly differnet outcomes in different individuals (Menard, Bandeen-Roche, & Chilcoat, 2004). Similarly, Baykal (2009) defines multifinality in open systems as the possibility to attain alternative objectives from the same inputs. In geo-spatial systems, in which resource optimization is a critical challenge, multifinality is increasingly more important—a select set of sensor systems being able to provide various geological data *in situ* (Bennett & Tang, 2007).

In all of the above definitions, if the contextual relevence is stripped out, the idea behind multifinality is exactly the same: being able to achieve several distinct outcomes from one system, product, or process.

When discussing technology-based social ventures, we believe that the concept of multifinality refers to designing a system where the individual actors and inputs, the subsystems, and their interactions all meet their own goals while the system as a whole also meets its goals (Stepler et al., 2010).

Relevance to Design & Business Strategy for Social Ventures

Analyzing a Wal-Mart store for multifinality, we may observe:

- a “profit-making system” from the perspective of management and owners;
- a “distribution system” from the perspective of the suppliers;
- an “employment system” from the perspective of employees;
- a “materials supply system” from the perspective of customers;
- an “entertainment system” from the perspective of loiterers;
- a “social system” from the perspective of local residents; and
- a “dating system” from the perspective of single customers.

Similarly, analyzing the Grameen Bank for multifinality, we observe:

- a “banking organization” from the perspective of a certain customer base;
- a “Microcredit Institution” from the perspective of a certain customer base;
- a “Social Capital Feedback System” from the perspective of customers;
- a “Social Network” from the perspective of group loan lendees;

- an "Employment System" from the perspective of employees;
- a "Training Institution" from the perspective of potential employees and participants; and
- a "National Economic Progress System" from the perspective of the Bangladeshi Government.

5.4.4 Tenet 4: Equifinality

von Bertalanffy (1971) defines equifinality as the principle that in open systems a given end state can be reached by many potential means. Weisbord (1987) implemented this definition in talking about productive businesses and states that firms may establish similar competitive advantages based on substantially different competencies, and these advantages may be called equifinal.

According to Mash and Wolfe (2005), in psychology equifinality refers to how different early experiences in life (e.g., parental divorce, physical abuse, parental substance abuse) can lead to similar outcomes (e.g., childhood depression). There are many different early experiences that can lead to the same psychological disorders. In environmental modeling studies, and especially in hydrological modeling, two models are equifinal if they lead to an equally acceptable or behavioral representation of the observed natural processes. (Beven & Binley, 1992; Beven & Freer, 2001). Croft (1996) defines equifinality in geomorphology as similar landforms arising as a result of several uniquely differnet set of processes.

Again, looking at technology-based social ventures, Stepler et al. (2010) define equifinality as the concept of convergence: attaining the same desired output through several different channels/inputs.

We define equifinality as the concept of being able to achieve similar end goals through varied processes. The social, economic, and environmental impacts of each process must be determined to identify the optimal process.

Relevance to Design & Business Strategy for Social Ventures

To understand the concept of equifinality, we analyze four independent ventures that manufacture and/or sell solar lighting systems in the Indian market.

Greenlight Planet: The problem they are addressing is that every year over US$38 billion is being spent on fossil/alternate fuel-based lighting systems like candles, kerosene lamps, and wood in India. As their solution, they sell cheap small-scale solar lamps. These lamps are mostly manufactured in China and sell in India for around US$20. Their justification for the process is that an individual spends approximately US$2/month on lighting using candles or kerosene lamps. Instead, if they were to either access a small loan, or save enough to purchase a US$20 solar lamp, they would break even in about 10 months, beyond which they would be saving money by using their solar lamps. Greenlight assures one year's warranty to its customers, during which they provide free on-site testing, training, and repair. On the social side, their value proposition promises a safer living environment by brighter non-polluting lighting and better community growth through their distribution network.

Selco-India: Selco is a solar lighting company operating in southern India. Their problem definition revolves around proving that poor people can indeed afford sustainable technology and that ventures with a social bottom line can operate as commercial enterprises. As part of their solution, they sell large-scale solar panels to groups for residential use, or to community based organization for the overall betterment of the community. Some of the most common uses documented are lighting, water pumping, telecommunication systems, and computing. To keep the per capita cost for solar energy down, they provide long-term support on maintenance and repair, thereby increasing the lifespan of their products. For people to be able to afford these, Selco has teamed up with none regional banks in the areas they serve to make available 3–5 year loans at 5% to 14% interest rates with 10–25% down payment. They thus have incentivized a culture of saving for communal growth. The more money a group can provide as down payment, the less interest they are charged. As part of their social bottom line, they provide first-hand training to their customers on how to install, set up, and maintain a solar system to obtain maximum efficiency out of it. At the same time, they seek out interested candidates and teach them all of the skills listed above by letting them shadow the current mechanics. Then, when these new candidates are ready, they can apply for a job at Selco or go the entrepreneurial route and open their own maintenance and repair business.

SEWA: The Self Employed Women's Association (SEWA) is a women's group that functions primarily in Gujarat, India, and promotes women's rights and entrepreneurship. Through various ventures, they enable their women members to learn how to manufacture cheap solar lamps. Through their networks with technical schools, learning material was developed, and a group of six women were taught how to make these lamps. From then on, these women served as the teachers for other SEWA members. SEWA's microfinance loan department helps interested women buy "kits" that include all the building materials. Women can buy these kits, invest time and sweat equity, and sell these lamps within or outside the SEWA network. Their eventual goal is for these women to serve as the medium for increasing green lighting around six states in India.

Barefoot College: Barefoot College is a non-profit based in Rajasthan, India that enables illiterate and semi-literate men and women from underserved communities in various countries to gain technical knowledge in solar power systems. Through the technical education program at Barefoot, they are taught the basics of manufacturing solar lanterns on a small scale, and then turning that into a business in their own communities. All the products developed at Barefoot are sold to households in neighboring communities, where each household pays a monthly fee. The monthly fee is determined by how much each family spends on kerosene, candles, torch batteries, and wood for lighting every month. The Village Environmental Energy Committee is responsible for making sure that the Barefoot solar engineers install, repair, and maintain all the solar units properly and are paid their stipend on time.

All of the above companies compete in the same industry. However, each company has increased the adoption rate of their product in a unique, innovative, and sustainable manner by either reducing the comparative cost, or demystifying solar technology and decentralizing its application at the grassroots level. They have each created similar kind of impact, varying in quantity and yet taken different approaches. This is classic equifinality.

5.4.5 Tenet 5: Differentiation

Senge (1990) defines differentiation as specialized units performing specialized functions within any given system. Knodt and Rasch (1994) follow up on Senge's definition by saying that differentiation is the property of distinguishing or discriminating between things, aspects, sub-systems, or processes as different and distinct. Differentiation enables interdependence which necessitates holism.

While referring to human psychology, Bowen(1974) states that differentiation is the capacity of a person to manage his or her emotions as well as thinking; their individuality as well as their connection to others. In the context of socio-economic changes within a society, Naustdalslid (1977) states that differentiation is a means of increasing the complexity of a system, since each subsystem can make different connections with other subsystems. It allows for more variation within the system in order to respond to variation in the environment.

In their research work on differentiation in large societal systems, Holmes et al. (2007) claim that in modern society, systems deal with the complexity of the environment that they reside in by significantly increasing the amount of differentiation created from that same environment. This is often accomplished through the creation of interdependent subsystems within a system and the.

We define differentiation as a method of inentifying individual specialized components of a large system whether the objective is to simplify said complex system, or consider the individual components in relation to each other and in relation to the entire system so as to increase the complexity of the system. In some special cases, differentiation is applied to a larger system, so as to simplify it into individual components, and then analyze those individual components in relation to each other, making it a complex two-step process.

Relevance to Design & Business Strategy for Social Ventures

We once again analyze the Kiva.org model and its individual sub-systems. While analyzing interdependence, we considered three independent systems: the internet, donating money in return for social goodwill, and seeking seed capital from a venture capitalist. We then approached these then systems from a holistic perspective and showed that they were interdependent. However, at the heart of both interdependence and holism lies differentiation. The internet is a sub-system in various major systems, as is money donation and seeking seed capital. However, for the Kiva.org model to work effectively, these integrated systems need to be demystified and analyzed individually, they need to be differentiated. Then we can analyze them together, in a holistic manner and identify their interdependencies.

5.4.6 Tenet 6: Regulation

Carr (1996) and Skittner (2006) define regulation as a method of feedback that is necessary for the system to operate predictably and counteract. Along the same lines, Stepler et al. (2010) conceptualize regulation as employing feedback to ensure that the system is actually working. Flood (2010), rather, interprets regulation more literally – a method to bring to conformity with rules or principles, or impose actual regulations.

All of the above definitions, however, could be evolved or emergent versions of Cannonn’s definition of regulation from 1932, when he suggeted that regulation is synonymus to homeostasis in general systems theory (Cannon, 1932). Homeostasis, many authors agree, is the property of a system, either open or closed, that regulates its internal environment and tends to maintain a stable, constant condition (Cannon, 1932; Tononi & Cirelli, 2003).

We suggest the following functional definition for regulation: a process of ensuring intrinsic feedback to ensure *desired* operation of the system and counteract entropy.

Relevance to Design & Business Strategy for Social Ventures

The Grameen Bank started as a microfinance institution. In 1976, Dr. Yunus had conducted a research study in Jobra village around Chittagong University where he taught economics. Based on his research, he discovered that very small loans could make a disproportionate difference to a poor person. Upon talking to several commercial bankers, he discovered that the largest problem with loaning to “poor” people was lack of a collateral. When he gave out his first set of loans from his personal account, he set up a meeting with several members of the community, along with the women he was providing the loans to. He was able to successfully recover 100% of the money he had loaned before the term of the loan had ended. He experimented with this strategy several times, each just as successful. When he developed the lending rules for Grameen Bank, a core philosophy was that loans would *only* be give to women, and they would have to be in groups of atleast six or more to become eligible. By lending only to groups, Grameen Bank leveraged each of the loanee’s social standing, a form of social collateral. In order to make sure that loans were repaid, every member of the group was liable to pay their share. If one of the women failed to contribute their share, all of the women would suffer, and this imposed social pressure. This was, and is Grameen Bank’s process of employing regulation—a feedback mechanism to ensure sustainability.

5.4.7 Tenet 7: Abstraction

We provide here several definitions from the literature for abstraction.

> “In philosophical terminology, abstraction is the thought process wherein ideas are distanced from objects” (Langer, 1953).

> “Abstraction is the process of extracting the underlying essence of a concept, removing any dependence on the real world objects with which it might originally have been connected, and generalizing it so that it has wider applications or matching among other abstract descriptions of equivalent phenomena.” (Diadochus, 2006)

> "Abstraction in philosophy is the process, or the alleged process, in concept-formation of recognizing some set of common features in individuals, and on that basis forming a concept of that feature." (Mackie & Force, 2007)

5.5 Interdependence, Holism, and Differentiation—The Interdependence

We analyzed interdependence, holism, and differentiation previously in the chapter. We also looked at how a social enterprise like Kiva.org might employ these tenets for optimizing their functions. During our research and while analyzing various case studies, we found a very intricate connection between the three tenets: in order to precisely analyze a system, it is essential to differentiate the various sub-systems and approach them from a holistic standpoint, so as to identify and establish various interdependencies between the sub-systems and how they relate to the whole. None of these tenets can exist without the other.

Saavedra, Earley, and van Dyne (1993) expressed a similar idea while relating to the interdependence between all living things. von Bertalanffy (1971) talked about the implicit differentiation between the properties of a given system, whether physical, biological, chemical, social, economic, mental, or linguistic, and the importance of looking at these unique sub-systems in a holistic manner. Recently, in a similar study, Flood (2010) defined holism as an emergent property of interdependent sub-systems while talked about applying systems thinking to action research.

Family systems theory is another good case for establihing the correlation between interdependence, holism, and differentiaiton. Mulej, Potocan, and Rosi (2005) talk about the ethics of interdependence regarding conflicts between holistic and specialist thinking. While holistic thinkers and specialists differ on most methodologies, there is absolute certainty that their actions are synergized by nuture.

They provide a very appropriate example about families. Two families living across the street from each other may each be comprised of a mother, father, and child. Yet it is in each family's rules of interacting with each other and their collective history that they are understood as uniquely different. In contrast, a non-systems approach would attempt to understand each family by looking at the individual members separately. By studying them individually, the way they interact, their communication, or their humor, their uniqueness is lost or clouded. A common analogy often used by family systems theorists and practitioners is found in baking. The cake that comes out of the oven is more than the eggs, flour, oil, sugar, baking soda, and vanilla that make up the parts or elements of the cake. It is how these elements combined to form something larger than the ingredients that make the cake. Such is true with families as well. It is more than "who makes up a family," it is how they come together that defines that family (Mulej, Potocan, & Rosi, 2005).

Based on these theories, we define these three independent tenets as one unified inter-reated aspect for future work: *symbiosis*. As an evolved tenet of systems thinking, we define symbiosis as the interdependence of differentiated independent sub-systems tied together in a holistic manner.

5.6 Systems Thinking and E-Spot Canvas—The Intersection

In this study, we have discussed the basics of systems thinking and then described seven tenets for it. The end-goal is to understand how the tenets of systems thinking interact with every decision made during the engineering process. For every tenet, an example relevant to the design or business case was presented so explain this relevancy.

The E-Spot canvas seeks to incorporate the tenets of systems thinking at various levels: interdependencies between different design factors, holistic design process for system development, multifinality from one project, equifinality in the form of back-up options, etc. These incorporations were touched upon during the case study in Chapter 3 and in all three case studies in Chapter 4.

In this section, however, these dependencies will be explained in detail by laying the tenets described earlier over the E-Spot Canvas. These interactions will then be demonstrated using an industry-based case study in Chapter 6.

The diagram in Figure 5.1 portrays the intersection between the tenets of systems thinking and the E-Spot canvas. These intersections are:

- Design: During the design phase, regulation is employed for defining the appropriate technologies. Significant feedback needs to be gathered on various technologies to make sure that the right options are chosen.

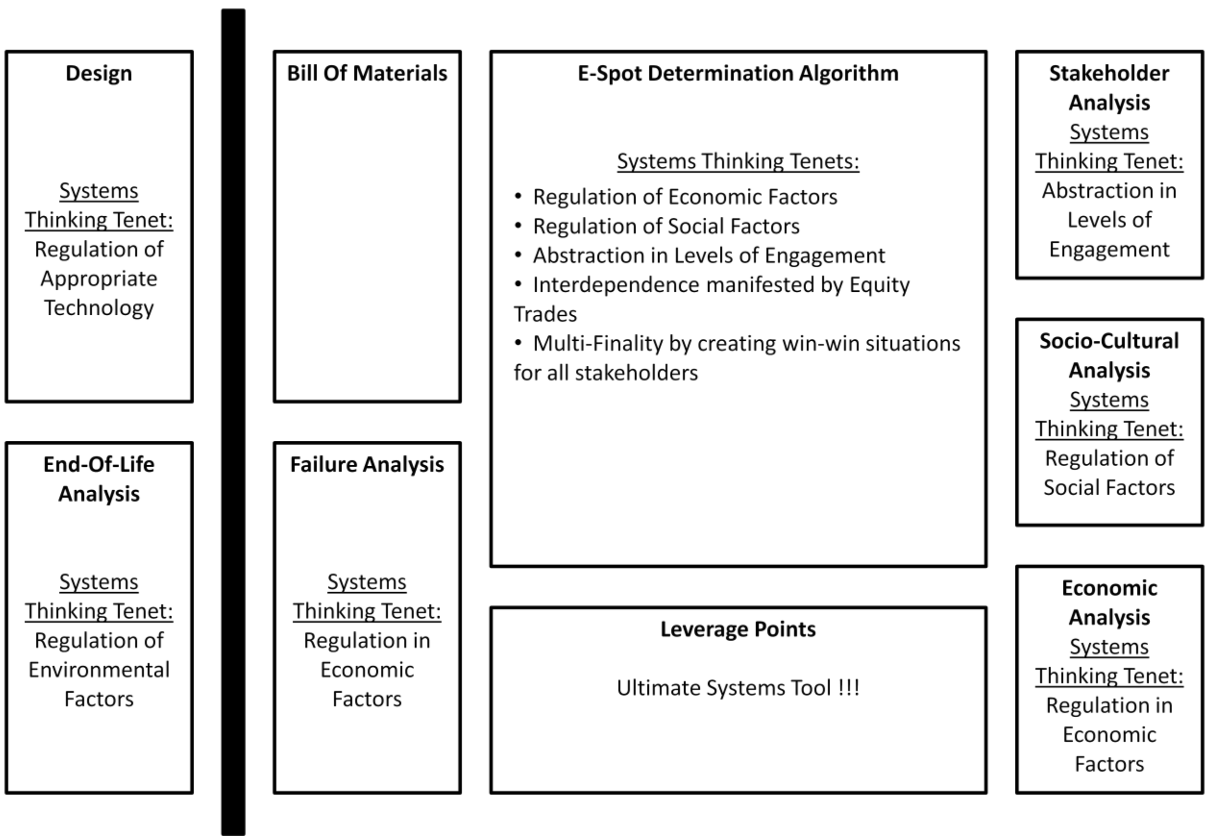

Figure 5.1: E-Spot Canvas and Systems Thinking – The Intersection

- End-of-Life: This phase relates directly to the environmental effects of various items used in the project, after their usable lives. This involves significant regulation of environmental factors.
- Failure Analysis: The goal of anticipating failures is to ensure that maintenance costs and minimized. Hence, regulation of economic factors is practiced to ensure a successful failure analysis.
- Stakeholder Analysis: This model emphasizes including any individual or entity that has any connection to the venture at any level as a stakeholder. This requires the project designer to abstract themselves at various levels to make sure that they have considered every stakeholder and identified the marginalized ones.
- Socio-Cultural Analysis: Analyzing various socio-cultural factors within a community requires constant verification and assessment of various community members, as well as that of local trends and behaviors. This feedback is a prime aspect of regulation in social factors.
- Economic Analysis: Understanding a community's financial attributes requires a keen understanding of and validated feedback from members of the community as well as other stakeholders. Economic analysis of a community required regulation of economic factors.
- Leverage Points: As has been explained earlier, identifying leverage nodes within a community requires the design team to employ various different skills and experiences. The most important of these skills is the application of the tenets of systems thinking. Hence, we refer to the "Leverage Points" block as the ultimate application of the tenets of systems thinking.

- E-Spot Determination Algorithm: As might be obvious, determining the E-Spot involves various tenets of systems thinking. It requires regulation of various economic and socio-cultural factors, applying abstraction at various levels of engagement, and interdependence manifested by different equity trades. Multifinality is achieved by creating win–win situations for various stakeholders, whereas equifinality is required to ensure that numerous options are evaluated for choosing the optimum solution.

5.7 Summary

Scientists and philosophers have long wrestled with the problem of how we understand and make sense of the world. There are both descriptive and prescriptive approaches to understanding our world. On the descriptive side, theories of cognition, perception, and thinking describe how humans organize stimuli and make sense out of them. On the prescriptive side there are two approaches to making sense of the world: one is reductionism and the other is a systems approach.

Systems theory has a long history in the realm of human knowledge. Some scholars trace the development of systems theory back to Aristotle. Most scholars attribute the idea of holism, central to systems thinking, to the German philosopher Hegel who stated that the whole was greater than the sum of its part. This idea is that systems consist of a number of interrelated and interconnected parts that, once put together, make the behavior of the whole different and distinct than the behavior of its individual parts. Holism asserts that we cannot understand the behavior of the whole by studying only the behavior of its various components.

Systems theory focuses on the relations between the parts. Rather than reducing an entity such as the human body into its parts or elements (e.g., organs or cells), systems theory focuses on the arrangement of and relations between the parts how they work together as a whole. The way the parts are organized and how they interact with each other determines the properties of that system. The behavior of the system is independent of the properties of the elements. This often referred to as a holistic approach to understanding phenomena.

The application of these principles is crucial to the E-Spot canvas. This application will be demonstrated in an elaborate case study in the next chapter.

Chapter 6

Intelligent Street Lighting: An E-Spot Case Study from Texas Instruments, Inc.

This chapter presents a case study for an intelligent street lighting system. However, this "project" is different than all the other ventures described in this thesis. In general, the other ventures presented in this thesis were designed for highly resource constrained and economically deprived communities. This case is a retrospective study for a project developed by Texas Instruments, Inc. based in Dallas, Texas for the city of Oslo, Norway. Accordingly, the context for this project is very different, as is the magnitude of the socio-economic scale; however, the basic value proposition offered by the E-Spot Canvas applies just as much to this project as it did to the bio-gas digester or husk power systems.

The primary reason for conducting this case study is to show that the E-Spot Canvas holds value not only in the development of social entrepreneurship ventures, but just as well for large-scale industry-based projects, where financial restraints are not the primary concern. The case study below attempts to demonstrate this concept.

6.1 Background Information:

Lighting represents 15–20% of the Norwegian annual electricity demand of 120 TWh. Street lighting is 3% of this total. In 1991, Norway was one of the first European countries that deregulated its electricity markets. Since then, both the traditional utilities and new actors have struggled to adapt and develop their services in order to meet new challenges. Based on various studies, street lighting was identified as a major area for optimization. Hafslund ASA–owned Viken-Nett is Norway's largest distribution company with over 575,000 commercial customers. Viken-Nett, along with its daughter company Ostnett, is also responsible for the operation and maintenance of over 250,000 street lighting points in the greater Oslo area. Viken-Nett and Ostnett have been persistent in the development of new concepts especially adapted to a deregulated electricity market that involve running, controlling, and administering street lighting. They have initiated several studies on the organization of the street lighting activities in general.

Today's systems are usually based on the "fixed operating hours" billing philosophy. Public service professionals only have a limited overview of the actual energy use in their systems. Hence, the end customers are billed based on an anticipated amount of operating hours and wattage use. The concept of intelligent road light enables direct measurement of the energy used and two-way communication with each individual fixture. Both the utility operator and the end user would benefit from more accurate measurements. Furthermore, the incentive structure for the actors to invest in more cost efficient systems would be clearer. Precise and correct billing is primarily of interest to the authorities responsible for collecting various taxes.

Focusing on the street lighting market within the United States, the 4.4 million streetlights in the ten largest metropolitan statistical areas use an estimated 3 billion kWh of electricity annually, producing the equivalent of 2.3 million metric tons of CO_2. If a 50% reduction in power could be achieved, it would amount to a saving of 1.5 billion kWh or 1.1 million metric tons of CO_2. Recent factors such as increasing petroleum prices and global economic downturns have created a significant need for smart lighting solutions. Two key drivers are:

Economic

Against a backdrop of the global economic slowdown, funding has becoming limited for most social programs. Streetlights are among a city's most important and expensive assets, typically accounting for a third of its electricity bill. With energy prices increasing, this is driving the demand for energy-conserving technologies for municipal lighting. Maintenance costs are also increasing, with huge numbers of lamps nearing the end of their serviceable life.

Environmental

The Kyoto Protocol compels signatory states to implement rigorous energy conservation programs. This, in turn, puts pressure on municipal bodies to reduce their CO_2 emissions. In addition, ecologically minded governments are responding to the reports of light pollution adversely affecting the nocturnal natural environment.

Intelligent lighting systems utilize the latest technologies to optimize the light intensity according to the situation by dimming the lamp. All lamps can be communicated with, so their condition can be assessed remotely and, if necessary, the lamp controlled remotely. The key benefits are:

Reduced energy costs

No city can simply switch off its lights at night, so other measures are called for. Not every street and road requires full illumination all the time. Therefore, depending on the site and situation, a frequently feasible option is to dim lights, thereby striking a balance between economical goals and citizens' safety needs. Dimming lights by up to 50% is generally imperceptible to the human eye and can show a 40% reduction in power use. Typically, lights would be dimmed during non-peak activity times between 11 pm and 5 am.

Reduced greenhouse gas emissions

With the energy savings comes a corresponding reduction in your community's CO_2 footprint. Each saving of 1500 kWh reduces CO_2 emissions by approximately 1 ton for mixed power generation.

Reduced maintenance costs

By automatically monitoring the mortality curve of each lamp fixture in a streetlight network, you can accurately predict lamp failures before they occur. This enables you to develop more efficient and cost-effective maintenance scheduling. Also, by intelligent control of the lamp, you can optimize its life-span.

Higher community satisfaction

With an intelligent streetlight system in place, you will be able to significantly improve the performance, efficiency, and reliability of the street lighting in your community. No longer do you need to rely on public complaints and visual inspections after sunset to monitor streetlight function and safety. Through its energy and maintenance reduction capabilities, you will also be able to free up a large allocation of public funds that could then contribute towards other community programs.

Fast payback

Intelligent streetlight systems are very cost-effective, with a typical payback period within five years. By first replacing the oldest lamps that have the most inefficient technology, this period can be shortened still further.

Information

Information is an increasingly valuable asset. If you can capture data on ambient temperature, moisture, visibility, light intensity, rain, and traffic density, you can further lower energy costs and roll out new services for your customers. These innovative applications can add additional value to your intelligent lighting system.

Convergence of existent technologies

Until recently, intelligent lighting networks mostly have been small-scale systems utilizing expensive technologies with a poor ROI. This makes them unsuitable for more general municipal lighting control. Many key technologies have now matured to bring low-cost sustainable intelligent lighting.

Large radio networks

Previously, radio networks utilized expensive hardware and were unreliable in large network configurations. TI manufactures wireless microcontrollers that are ideally suited to streetlight control, with a very low cost-point and long transmission range. The ZigBee networking software maintains the network structure, self-healing the network around any nodes that may have suffered a fault. These networks can have up to 1000 nodes and will automatically reform following any power disruptions. Further, with multiple radio channels, multiple networks can co-exist together. The underlying protocols use internationally recognized standards and the license-free 2.4-GHz radio band is available across the world.

Network management center

The control centre technology utilizes a server to maintain the database of streetlights. Individual streetlight networks can communicate with the data center via a wide number of technologies such as GPRS, GSM, and Ethernet. These technologies form the standard approach to gathering remote data. A utility can then monitor their streetlight networks from practically any location in the world using a desktop PC and a connection to the internet. All these technologies are now very cost-effective to implement.

Lighting technology evolution

Lamp technology has been improving in efficiency and performance for the past 30 years. Lamp control has become more efficient with the move from mechanical ballasts to electronic ballasts, and the lamp technology has evolved from High Intensity Discharge (HID) mercury vapor to sodium and metal halide. The recent developments in LED technology have resulted in a further leap in efficiency.

LEDs are becoming more widespread as they meet standard regulations for environmental challenges, as well as improving streetlight quality through features like reduced glare and better color rendering. Current LED solutions have a low power consumptions of under 35 W (Phillips Luxeon Rebel) and offer energy savings of as much as 52% over mercury vapor HID and 26% over a sodium HID fixture (90 W). LEDs have a much higher initial cost, but the longer lifetime of 60000 hours translates into a 10- to 15-year lifetime, which is at least three times that of HID lamps. This reduces maintenance costs and, combined with the energy savings, means that municipalities can recoup the costs of a basic non-networked LED-based street lighting installation in four-to-six years. LEDs also facilitate low-cost dimming control when compared to the expense of adding dimmable electronic ballasts to HID lamps.

6.2 TI's Technology for Intelligent Street Lighting Systems

6.2.1 Introduction

TI, as the world's largest analog semiconductor company, has a stake in many aspects of a street lighting system. Accordingly, system engineers at TI have developed the block diagram shown in Figure 6-1. As depicted by this diagram (colored items), TI owns stake in sensing, controls, power conversion, LED drivers, and large scale communication systems.

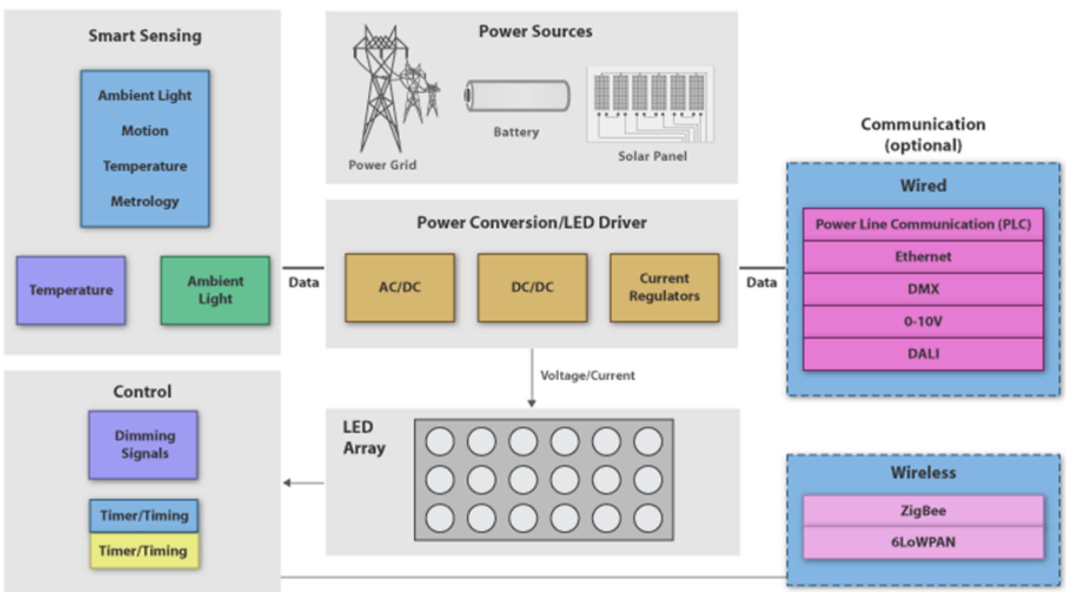

Figure 6-1: System Block Diagram for an Intelligent Street Lighting System

6.2.2 How It Works

The short range of wireless communication is overcome in a network by hopping messages across the network. In this way, ranges of many tens of km can be achieved using low-cost radio technology.

Streetlights are ideal for wireless communication because they have the height, which enables wireless service coverage of 350 m or more, and the spacing of streetlights means that many lights are in range of each other. Hence, if a node were to fail, an alternative route could be found. The streetlights must be powered, so this energy is also available for the wireless streetlight controller.

An idealized network is shown below in Figure 6-2. The network selects the connections automatically and would find the optimal route.

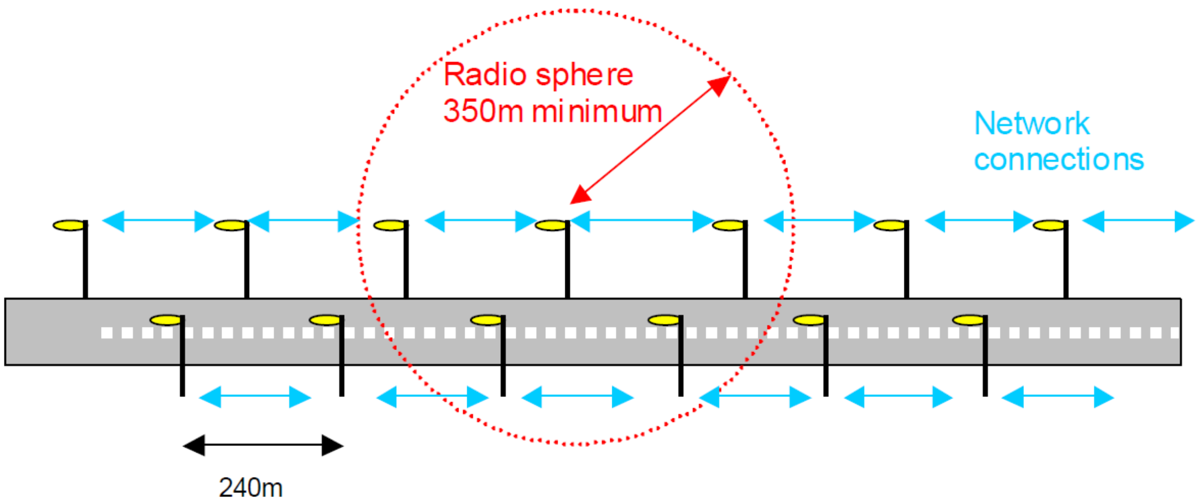

Figure 6-2: Typical Streetlight Network

Each lamp controller communicates with the data center via a gateway. Typically 500 streetlights will be associated with one gateway. The network structure is a tree, which could be of any shape. For example, long and thin for highways and dense "bush" shaped in car parking areas. At the root of the tree is the gateway.

The network topology is handled automatically by the control software, which maintains the optimum network shape and will self-heal from any failures within the network. The street lighting application simply submits and receives data packets from the network software, which will route the messages to the appropriate destination.

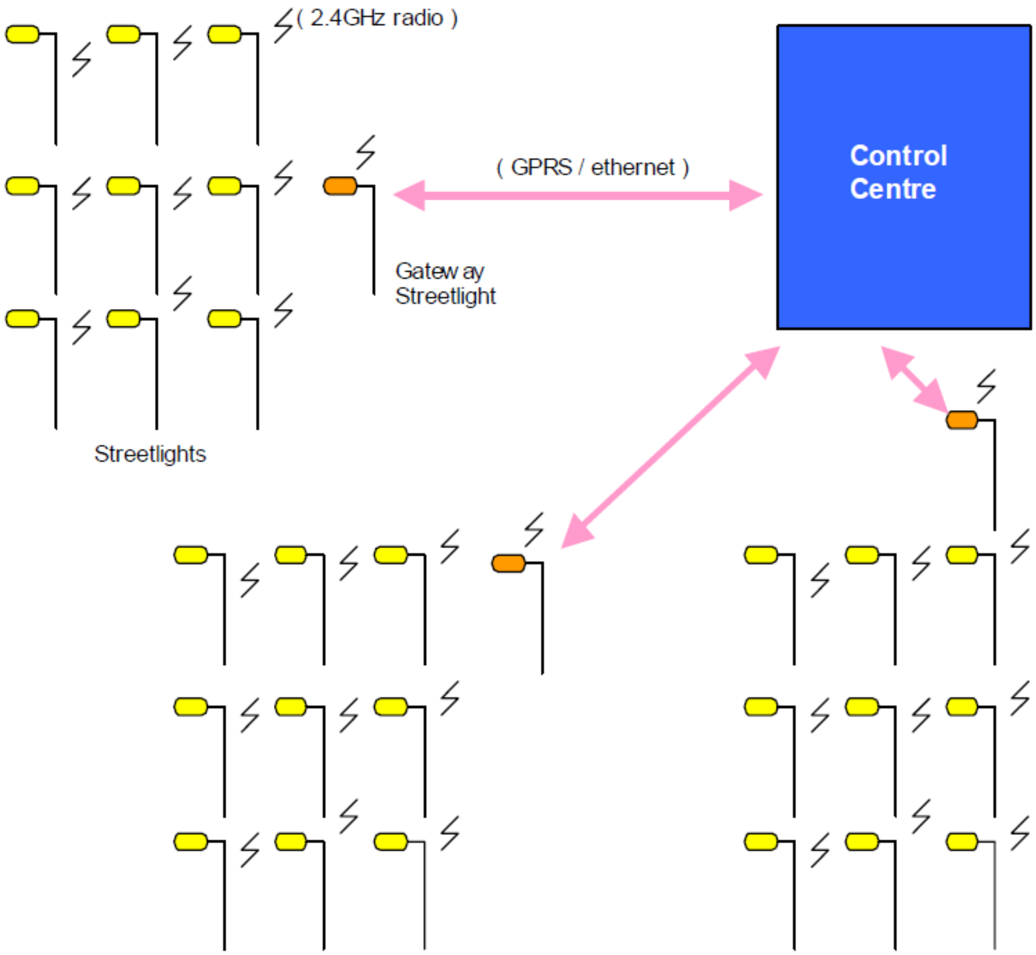

Figure 6-3: Street Lighting System Components

The control center consists of a large database with all the streetlights updating the database every 15 minutes with sensor readings and lamp-life data. Using this data, the servers can automatically dim some or all of the lamps by sending messages into the network. The control software can be optimized to handle the recovery of long thin networks from faults, which present the greatest challenge to wireless network design.

Scalability

The TI developed system is highly scalable. You can add nodes anywhere in the network and the network software will look after the connections automatically. If one network becomes full, this system can allow seamless load balancing of the network, transferring lamps from the heavily loaded network to a less loaded network.

Any municipal council can develop a system at a pace that is comfortable with the municipal street lighting budget and resource constraints. For example, by replacing lamps at the end of their life and fixtures with the highest operating costs (such as those with 250 W or higher), a council can benefit from immediate energy savings while you wait for additional resources. Once the resources are available, you can then continue to install the lamps in phases, allowing the network to automatically link in with the initial lamps.

Global deployment

TI’s wireless communications use the 2.4-GHz band, which is license-free and available globally, so any product that is developed utilizing this technology requires no additional engineering for overseas markets.

Future proof architecture

TI processors have highly flexible signal control and could accommodate any light sources, such as Light Emitting Diodes (LED) and electronic ballasts.

Value added features

Once a wireless intelligent lighting system has been implemented, the infrastructure can then be expanded for various value added features.

Lighting control opportunities

- During an emergency, illuminate the area at maximum intensity;
- Illuminate areas of road maintenance;

- Give police authorities control of localized street lighting to increase the safety of officers during night-time operations; and
- Develop and implement adaptive-lighting protocols that can optimize the performance of street lighting networks while maintaining high level of public safety. Different districts have different demands, for example, residential and commercial

Increased energy savings

- Pedestrian and traffic motion sensors to light a street on demand;
- Pedestrian streetlight control via push-switch or mobile phone text message;
- The use of an astronomical clock, to make best use of the light from the Sun and Moon; and
- Automatic dimming of streetlights based on the local weather and traffic density.

Information management

- Light performance auditing could reduce a city's liability exposure. For example, in the event of a lawsuit brought against the city for an accident, the system can accurately report the status and light output of any area by date and time of day;
- Data collected from traffic sensors could feed into the traffic management system;
- Data collected from temperature sensors could feed into highway maintenance operations during cold weather, giving real-time thermal mapping of the network;
- If GPS location data is entered into the database for each streetlight, then by integrating into a mapping system such as Google Earth or Microsoft MapPoint® Server or your own asset management system, you will be able to develop the most efficient routes for predictive lamp maintenance; and

- If power usage is monitored at the street lamp then this data can be used for billing of the electricity usage.

Further opportunities

- Pole damage detection with the addition of a suitable sensor;
- Taxi call buttons on lamp posts to signal to the network management center to generate a taxi call to the appropriate location;
- If the system has traffic speed sensors then this information could be used to manage traffic speed via the dimming of the streetlights. If the average traffic speed is too fast during evening and night hours, this could be used to trigger a slight dimming of the streetlights. The level of dimming would be imperceptible to motorists but they would slow down, regardless, in response to the slightly diminished lighting. A 5% light reduction slows traffic but is not noticeable to motorists; and
- With the added intelligence in the lamp, you can add additional features to increase HID lamp life, such as softer start-up and protection against re-igniting an already hot HID lamp, since this shortens the lamp life.

The North American Electric Reliability Council (NERC) estimates that demand for electricity in the U.S. will grow by over 19% during the next decade. Over the same period, electricity generation is projected to grow by only 6%. The Brattle Group, in a recent analysis of current and future electricity needs, observed that there is too little time to expand the nation's generating capacity. One opportunity to address the demand side of this issue is to save electricity via the introduction of intelligent lighting technology to municipal street lighting. When you consider that there are an estimated 55 million streetlights in the U.S., the savings could be enormous. TI offers a technical solution to the implementation of wireless intelligent street lighting networks.

6.3 Mapping the E-Spot Canvas

6.3.1 Design

As with any engineering design, several large scale solutions to an industrial street lighting system exist. Various factors could influence these designs. The solution designed by TI has been demonstrated in Figure 6-1. The block diagram in Figure 6-1 will be analyzed for the purpose of this case-study.

Ten primary factors were considered during the design process for the optimum TI solution.

1. Input Voltage Range: Depending on the country where this system would be implemented, there might be numerous input voltage ranges. These are: 90–135 VAC, 207–253 VAC, 277 VAC, or 480 VAC. While a country's national electric system is the primary driver, other factors such as the number of LEDs, environmental factors, network communication system, and employed sensing systems might play a key role in deciding the operating voltage.
2. Power Factor Correction: Based on the region of operation, a power factor correction of 0.7 to 0.9 could be applied. Aspects affecting the PFC are the input voltage range, thermal consideration, environmental considerations, and system metrology.
3. Number of LEDs: The number of LEDs used per street lamp depends on the maximum amount of light output desired in lumens. LED configuration, type of drivers, and system metrology along with the environmental conditions will affect the number of LEDs required per lamp.

4. <u>LED Configuration</u>: Based on various factors, LEDs can be configured as either series, parallel, or a combination of these methods. These factors may include the available system power (voltage and current), number of LEDs, type of driver, environmental conditions, metrology, and sensing data required.

5. <u>Type of LED Drivers</u>: Numerous types of drivers are available for LEDs: Constant Current, Constant Voltage, Buck, Boost, Buck–Boost, SEPIC, PFET-based, floating type, etc. (TI Options shown in Figure 6-4). The type of driver required depends on the input voltage, number of LEDs, LED configuration, design metrology, and sensing system requirement.

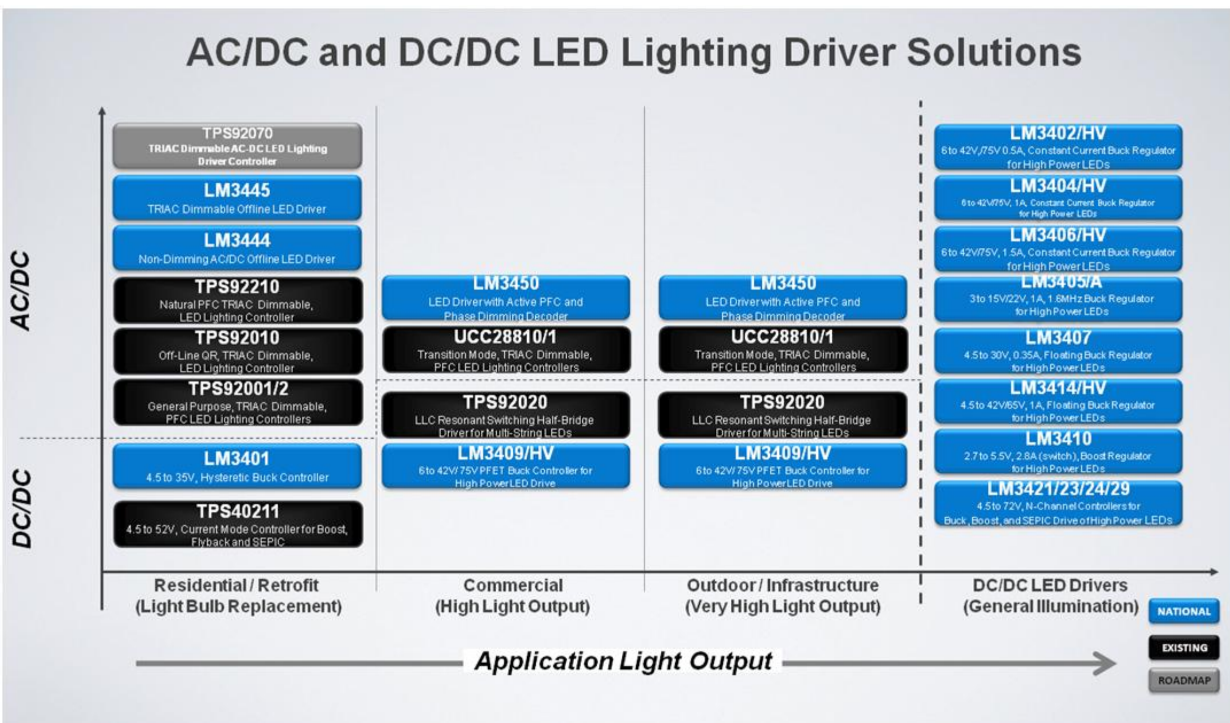

Figure 6-4: LED Drivers Portfolio by ‘TI’ and ‘National by TI’

6. <u>Thermal Considerations</u>: For any system involving high-end electronics, it is very important to consider how much heat will be generated by the system, as well as how

much heat is present in the environment. Hence the major considerations are environmental conditions, number of LEDs, input voltage range, and metrology.

7. Environmental Considerations: Environmental considerations are agnostic to any design parameters. However, almost every design parameter is affected by a change in environment.
8. Network Communication System: Several different communication systems could be used to manage the system based on the overall needs and design aspects: PLC, ZigBee, 6LoWPAN, GSM, etc. Three major factors affecting the communication system chosen are the operating voltage, environmental conditions, and sensing data requirements.
9. Metrology: Metrology is defined by the International Bureau of Weights and Measures as the science of measurement, embracing both experimental and theoretical determinations at any level of uncertainty in any field of science and technology (International Organisation for Standardisation, 2007). Metrology will be affected by every aspect of this system, as each aspect will have certain measurements.
10. Sensing Systems: To design an intelligent lighting system, every signal will need to be sensed and fed back to create a closed-loop network. The sensing system is dependent upon the input voltage, number of LEDs, type of driver, heat generation, environment, and type of measurement.

In the above design, ten independent factors have been considered as points of optimization. However, every factor either depends on other factors, or affects other factors; the individual factors are interdependent on each other. At that same time, the above ten factors need to be considered together in a holistic manner in order to understand the street lighting system. As discussed in Chapter 5, these factors are in *synergy* with each other.

6.3.2 Bill of Materials

Table 6-1: Bill of Materials for construction of a biogas digester

Money	**Time** [Time + non-labor intensive work]	**Sweat** [Time + labor intensive work]	**Other**
Integrated Power Grid, Batteries and Solar Panels for charge Top-Up	Environmental Survey for development of every other aspect dependent on these issues	Construction of control rooms for new lighting grid management	Extensive system design experience
AC/DC Converters	Code development for sensing system (Sensor decision + calibration)	PCB Manufacturing based on circuit design	Software development experience with specific MPU/DSP families
DC/DC Converters, Regulators & Drivers	LED Array study and configuration setup based on light output	Soldering of various assorted circuits	Knowledge of global engineering practices
Current Regulators	User habit analysis for development of 'Smart' control system	ZigBee Communication Node setup	Powerful networks to foster development connections and contracts
Smart sensing system MPUs	Metrology study based on national measuring system		
Various Sensors	Ground study for ZigBee node setup		
Timers	Circuitry design for new lighting system		
System Control MPU/DSPs	Communication channel security assessment, development and implementation		
Communication System (PLC, Ethernet and ZigBee)	Solar harnessing system setup		
LED Arrays	QA/TQM		

6.3.3 End of Life Analysis

A detailed end of life analysis was conducted for every item listed in the bill of materials under the "money" column.

- Integrated power grid, batteries and solar panels: A base assumption made is that any municipal council wanting to implement a smart street lighting solution has a power grid laid already. Batteries are installed on every lamp post to put the least amount of constant load on the power grid, making the system highly efficient. State-of-the-art technology assures that these batteries usually have a lifespan of about 8–10 years. At the end of this period, these batteries may either be reused in applications where a poorer quality battery may be acceptable, or recycled according to international battery recycling standards. Solar panels are integrated into the power system to harness natural resources as a way to reduce the load on the line power. Many newer companies sell solar panels with integrated recycling plans at end of life.
- Electronic circuit components: Various electronic components and circuit boards are used in the development of the system. These electronic circuitries will be recycled as per the country's electronics recycling program. Many of the individual components might be resold to companies or individuals for reuse after decommissioning.

6.3.4 Failure Analysis

The failure analysis is conducted in two phases. In phase 1, the routine maintenance for the items listed is completed, along with detailed timelines. In phase 2, any errors or failure modes brought on due to wear and tear or other natural reasons are anticipated, with approximate timelines. Table 6-2 outlines the failure analysis for the intelligent street lighting system.

Table 6-2: Bill of Materials for routine maintenance and specific failures of an intelligent street lighting system

Routine Maintenance	**Money**	**Time**	**Sweat**
@3 Mo			
@1 Yr	Sensor replacement for ensured performance	Perform system maintenance check and sensor recalibration	
@3 Yr		Change LED Arrays	
@10 Yr			

Failure Modes	**Money**	**Time**	**Sweat**
Short Circuit	Replace protective circuitry	Re-analyze enclosure	Fix broken casing/ Replace casing
Over-Heating	Replace any circuitry that may have been damaged	Design better heat-sinking for sensitive circuitry	
LED burn-out	Replace damaged LED clusters	Many factors could cause burn-out of LED before lifetime, identify reason	

After the above matrices for all of the required forms of equity; installation, routine obtaining maintenance and failure modes, the next step is to analyze the stakeholders of the project/venture.

6.3.5 Stakeholder Analysis

The goal of the Stakeholder Analysis (Table 6-3) is to assess every major player within the project community and classify them into three categories: Primary, Secondary, and Tertiary stakeholders. Amongst these stakeholders, identifying the marginalized stakeholders is very important.

Table 6-3: List of Stakeholders classified as Primary, Secondary or Tertiary

Primary	Secondary	Tertiary
Municipal Councils	Power Team at TI	TI Corporate
End-user (General Public in city of implementation)	Modular and Versatile Reference Kit Division at TI	Local Power Utility Company
End-Equipment Team @ Texas Instruments (TI)	MSP Group at TI	Emergency Service Crews
Department of Transportation / Department of Motor Vehicles	Cree / Philips LumiLEDs (LED Manufacturers)	Local Policing Authority
	Wireless Business Unit at TI	
	Tenergy (Industrial grade Rechargeable Battery Manufacturer)	

Based on initial assumptions, the above stakeholders were identified and validated. However, they were classified as primary, secondary, or tertiary stakeholders only after learning more about their needs, expectations, capabilities and limitations during fieldwork. Several secondary and tertiary stakeholders were neither expected nor identified by the engineering design team from TI. They identified themselves to the team and negotiated their inclusion as stakeholders—how a smart lighting solution would benefit them and what they could provide in return.

It is also important to note that various groups and teams within TI have been identified as independent stakeholders of this project. TI employs a holistic and interdependent management process. While this project benefits and furthers TI's corporate economic as well as social bottom line, the individual groups may meet their own annual goals, develop reference designs, conduct field research, and test new products, thus furthering their own goals and achievements. It may also be noted that the End-Equipment Team (EET) is the only entity within TI that is identified as a primary stakeholder. EET's goal is to remain agnostic to other business units and product lines within the company and ensure the development of a reliable and sustainable solution as per customer requirements, so as to uphold TI's strict moral standards.

6.3.6 Socio–Cultural Analysis

Community assessment from a social and economic perspective is essential to understand the community's needs, resources, and potential challenges. The objective of this analysis was to identify and highlight collaborators, on-the-ground champions, and potential troublemakers. After a thorough analysis of the involved engineering community, we identified the following socio-cultural issues:

- <u>A company with many divisions</u>: Every division at TI is independent. They manage their own product sales and marketing. Thus, every division wants to further their own revenue and it is essential to make sure that they can do so. This often creates a contradictory situation between creating an optimized solution using competitor parts and further revenue for one of TI's internal divisions.
- <u>Over-engineering Human Lives</u>: Based on the market survey presented to us by our customer, a major social concern with the design of a private company deciding and controlling the "effective" use of street lights. Since the company is privately owned and thus run for profit, how can ethical operation in terms of timing and "smart control" be guaranteed?
- <u>Environmental safety vs. commonwealth utility</u>: A primary driver for implementing a smart street lighting solution is to reduce wasteful utilization of electricity, thereby reducing the carbon footprint for a city. However, willfully convincing a city of

literally imposing darkness during the night is not an easy argument. How can a meaningful conclusion be reached in this matter?

- Liability: There are numerous direct legal implications of introducing a street lighting system that turns off in low usage hours—they are low usage hours, not *no* usage hours. If any civilian pedestrian got hurt on a street because a light failed to turn on, whose responsibility would it be? If a civilian was mugged or robbed on a street because the perpetrator had the cover of darkness, who would be liable? These are important questions that certainly need to be answered to implement a well rounded system.

6.3.7 Economic Analysis

Based on the list of stakeholders, we then analyzed the economic conditions of the stakeholders in the specific geographical area with the goal of building an economic model of the target market. Some of the factors analyzed, along with the (approximate) financial amounts, were:

- Average Annual GDP of Norway: US$381.77 Billion
- Average Annual Electric Consumption: 120 TWh (120×10^{12} Wh)
- Operating Profit of Power Industry: US$5.3 Billion
- Electricity used on Street Lighting Applications: ~4 TWh
- Average per capita income: ~US$56,900

6.3.8 Leverage Points

After studying various power relationships off the community and analyzing the social dynamics, we identified the following potential leverage points:

- End-Equipment Solutions & Applications Team (EESA): The End Equipment team remains agnostic to different business units within TI and develops solutions that create customer value. They leverage expertise from various groups within the company. As such, the EESA team functions like an expert think-tank. However, this also implies that ideal solutions created by EESA team often involve using a direct competitor's products over TI's own. The primary advantage of using a competitor's better product is to uphold TI's image as an ethical organization.
- System block diagram development: The EEST develops and keeps updated over 100 system block diagrams hosted on the TI website. These SBDs are all past projects developed for a customer that can now be leveraged by any system designer in either industry or academia. Several new product ideas have been developed by engineers and students and pitched to TI. As of 2009, 267 patents had been issued to product designs developed based on these SBDs.
- ZigBee as a global networking protocol: The intelligent street lighting system proposed in this case used the ZigBee networking protocol IEEE protocol 802.15.4. This provides TI leverage in two aspects. ZigBee was originally designed by a company called ChipCon, which is now owned by TI. Thus every system designed with ZigBee directly furthers TI's revenue growth. ZigBee is a global wireless industrial control network protocol. Hence, it requires virtually no modification in terms of software development for deployment in a different country.

6.3.9 E-Spot Determination

Based on the results of all the individual blocks on the canvas, we developed the E-Spot matrix shown in Table 6-4 for installation of the system:

Table 6-4: E-Spot Determination Matrix for Installation of a biogas digester

Stakeholders	Installation		
	Money	**Time**	**Sweat**
Municipal Council	System development	Ground Study for ZigBee Node Setup	All physical construction for new system
	Materials and Supplies	Communication channel security assessment	ZigBee node setup
		QA/TQM	
End User	End-payee in the form of taxes		
DoT/DMV		User habit analysis for developing 'Smart' parameters	
Texas Instruments	Long term system development	Environmental Survey for system development	All electrical manufacturing
		Code Development	
		Metrology study based on National Standards	
		Communication channel security assessment	
		QA/TQM	
Power Utility Company	Upgrading power grid to work with smart lighting system	Solar Energy harnessing system development	Installation of solar energy harnessing system

The Intelligent Street Lighting System described in this case study needed various levels of analysis to develop an inherently sustainable solution. This was achieved primarily by managing the equity distribution in a manner so that every stakeholder had the opportunity to win, only if they provided their contribution to the system. Five major, independent stakeholders were identified for this project. Table 6-4 describes exactly what each of those stakeholders are responsible for.

While mapping the E-Spot matrix, we realized that DoT/DMV and the utility company had a lot to gain out of the system but they did not have any stake to provide to the venture. Based on the BoM from Table 6-1, the design team assessed that the best option for the utility company was to work on developing a solar energy harnessing system as this was a direct add-on to their existing system. Similarly, the DoT/DMV along with the policing forces was put in charge of assessing user habits and developing a plan for the smart system design. From an investment standpoint, the load would be divided between the municipal council planning to implement solution and TI. This approach divided the responsibilities between various direct stakeholders in a balanced amount where everyone had a responsibility and a direct gain. These unique solutions emerged due the equity mapping carried out through the E-Spot Canvas. Intelligent Street Lighting systems based on these principles have been implemented in several large cities in many European countries.

6.4 Summary

The model intelligent street lighting system described in this case study chapter has been implemented by the city of Oslo. The final design implemented was quite similar to the one described here; however, for various legal and ethical reasons, the actual final design may not be disclosed. However, while helping us on the development of this case, various design managers associated with this project mentioned that a practical tool such as the E-Spot Canvas would have been immensely valuable when the design was being developed. This retrospective study also helped clarify to the engineering team several of the equity trades made by involving the abstract and marginalized stakeholders such as the police department, other emergency personnel, DoT, etc.

This feedback is crucial in that it provides good validation to the idea of working with industry experts in order to modify the E-Spot Canvas to accommodate for such large industrial projects. Some ideas related to this will be discussed in the future work section (Section 7.5).

Chapter 7

Model Summary and Future Work

7.1 Introduction

This study advocates the need for a tool that allows the designer of a social venture to efficiently match the equities between various stakeholders. In previous chapters, we have discussed the basic concept of the E-Spot Model and the academic background in which it was developed. We also discussed the relevance of implementing systems thinking within the E-Spot Canvas to ensure sustainability, with its four hallmarks. The goal, now, is to develop a detailed workflow of exactly how to use the E-Spot Model.

The popularity of academic as well as co-curricular involvement of students in social service programs and ventures has risen significantly over the past five years. Programs like Engineers for a Sustainable World, Global Social & Sustainable Enterprise, HESE, etc. have highlighted a need for "helping" people in struggling communities. Unfortunately, a majority of such programs are organized and focused on satisfying a student's desire to volunteer, rather than creating meaningful sustainable value for the receiver. This perspective needs to be altered. While well-meaning, this approach fails at creating real value and often, in fact, hurts the people being helped by making them further dependent on foreign help. When traveling through central African countries, one comes across various sights of broken windmills or solar dryers. These are often built by a visiting group of students from a western university. However, by their innate nature, these mechanical systems fail or break down due to lack of maintenance. The lack of a sustainable business/implementation model usually means that there neither may be any money, nor any knowledge base to carry out repairs. As student involvement in social ventures increases, so does the need to develop an evolved and efficient model that allows foreign groups to develop ventures in these communities, and then effectively transfer required knowledge to the locals so that these systems can be maintained.

Various models exist for developing business strategies. However, all of these models lack a structured approach for developing implementation strategies. Moreover, these advanced business model decision tools are developed for high budget ventures in western countries with abundant resources. They fail grossly at understanding the requirements for developing business strategies and implementation plans for social ventures in highly resource constrained environments. The E-Spot Canvas helps in developing practical and implementable action items for creating self-sustaining social micro-enterprises in developing communities. Chapters 3 and 4 discussed three real-world examples of how the E-Spot Canvas can be used not only for the development of unique implementation, marketing and management strategies for social ventures, but also for analyzing existing ventures in terms of their effectiveness at creating win–win situations for all involved stakeholders and identifying new ones.

7.2 Learning Objectives

The E-Spot Canvas seeks to illustrate a means of finding & tracking the optimum intersection between time, money, sweat, and other equities (credibility, contact, etc.) from the various stakeholders in the venture in the backdrop of the economic and social context.

This is referred to as the “equilibrium spot”, or the E-Spot. The model will be used to locate the E-Spot for the implementation, sustainability, and scalability of the venture. A primary objective for the E-Spot Canvas is to calculate the time, money, sweat, and other equity required for the installation, sustainability, and scalability of the appropriate technology products. We defined these equities as:

a. Money: money or other material support
b. Time: Time + non-labor intensive work
c. Sweat: Time + labor-intensive work
d. Other equity: Knowledge, Credibility, Social Capital, Trust, etc.

Once we identify the various forms of equity, the next goal is to find stakeholders, who can provide these equities. We define who the stakeholders are and what their capabilities and limitations are. We need to know the kinds of equity they can invest in the venture. Another objective is to identify stakeholders who have conventionally been marginalized, and ensure that they are matched with the right form of equity. Another learning objective for social entrepreneurs is to understand not only immediate problems but also the larger social system and its interdependencies; this understanding allows for the introduction of new paradigms at critical leverage points that can lead to cascades of mutually-reinforcing changes that create and sustain transformed social arrangements. Deconstructing the social situations with a specific focus on the distribution of power and money, gender roles, opinion leaders, etc. will help these entrepreneurs better understand the social environment. This in turn will lead us to marginalized stakeholders and resources not considered earlier. It will help us identify key nodes in the network that need to be “addressed”—key players in the game that need to be strengthened or weakened. These nodes will ultimately manifest themselves as key leverage points in the equity model where an intervention is needed.

The ultimate objective for the E-Spot Canvas is to develop "Sustainable" projects. However, sustainability is a highly user-defined term: there is no standard definition of sustainability. We identify sustainability through four hallmarks:

- Technologically Appropriate: The project should be designed using technologies that already exist within the community where the venture will be implemented. It should be accessible to the target audience. Hence, the E-Spot Canvas conducts a detailed design process for appropriate technologies.
- Environmentally Benign: The environment in most developing countries is often quite damaged. If the venture cannot reduce environmental pollution, it should at least add the minimum amount possible.
- Economically Sustainable: When working in communities that survive mostly on less US$1 per day, it is extremely important that a highly lucrative and effective business model exists that can make a profit large enough to cover operation, maintenance, and breakdown costs. It is also important to ensure that people outside of the formal economy, those who have no money to pay for services, are also accounted for.
- Socially Acceptable: Beyond all other requirements, it is important for a project designer in a developing economy to know that your product is actually required or that your customers want it. If it does not add value to the customer socially, the venture will never survive and be sustainable.

7.3 E-Spot Canvas: How Can One Use It?

We have implemented the E-Spot Canvas for various projects, as well as conducted post-implementation case studies. Based on the experience of these ventures, a process was developed for using the canvas. There are seven steps for using the canvas:

7.3.1 Step 1: Developing a design & identifying the BoM

The first step is to work with subject experts and community leaders to develop or decide upon the core technology for the venture. This is an iterative process. It is critical to make sure that the technology is either already present within the community or can easily be assimilated amongst the end-users. Once a design is developed, set up a Bill of Materials table based on the four types of equities covered earlier (money, time, sweat, and other). This will give the facilitator(s) a detailed understanding of exactly what will be needed for the venture.

7.3.2 Step 2: Conduct a Failure Analysis

The goal of this step if to find answers to questions like such as: What will happen when the system has a certain type of failure? Who is responsible for fixing the issue? Who will pay for the repairs? Who is the decision maker in such situations? How can ethical operation of the system as well as that of the repair process be guaranteed? The end objective for the failure analysis is to identify what are the most common failures that can occur in the system and exactly how, when and by whom will they be fixed.

7.3.3 Step 3: End-of-Life Analysis

In any system, parts will eventually break to the point where they cannot be fixed. This is especially true when the system is implemented in rough environments in developing economies. What exactly will happen when an item on your system reaches the end of its useful life? The goal of this block is to minimize the amount of waste generated and to reduce the carbon footprint of the venture. There might be items on the BoM for which no decent EoL plan exists. They should either be replaced or a new EoL plan should be developed.

Steps 1, 2, and 3 are carried out in a iterative manner until the ultimate point has been reached where the design maintains balance between easy implementation and a cradle-to-cradle process.

7.3.4 Step 4: Stakeholder Analysis

At this point in the process, a detailed list of all required materials for the installation and sustainability of the system have been identified. The next few steps help identify the people who can provide those resources and equities. The first of these steps is to identify every individual, group, and organization that is associated to the project, or who has anything to gain from the project. These will be your stakeholders. Once these stakeholders have been identified, the next goal is to classify them as either primary, secondary, or tertiary. This distribution is based on a stakeholder's involvement within the project. What form of equity do they offer? What is their level of gain from the project? How deeply are they involved and/or affected? These decisions are made based on a "gut-feeling" of the stakeholders. For this reason, it is extremely important that the E-Spot Canvas be developed as a group that includes all stakeholders, relevant authorities, and all other associated groups.

7.3.5 Step 5: Socio-Cultural and Economic Analysis

Once stakeholders have been identified, the next step is to deconstruct the community to identify social, cultural, and economic factors that directly impact the project. What are the community’s social habits? How do they live their life? What are they interested in? What are their cultural practices? Can some generalizations be made about the community’s “culture”, from both a micro and macro perspective? How much money do community members make? How much of their earnings can they save?

As already stated in the previous step, it is imperative to the success of the process that the design team gathers all the stakeholders and important community leaders over several days in order to gather the information required.

7.3.6 Step 6: Identify Leverage Points

Once stakeholders have been identified, the next goal is to deconstruct various relationships within the community: those associated with factors such as power, money, gender, governmental authorities, religion, etc. These relationships help identify various popular naysayers who can create hurdles in the implementation of your project, as well as opinion leaders who can help counteract the naysayers or convince the skeptics. They can also help find key individuals and issues that need to be engaged in the implementation process.

Most importantly, the main goal behind doing a detailed social deconstruction is to ensure that power is not simply destabilized within the system. Conventionally, systems have a set of winners and losers. It is important to make sure that the implementation of your project does not destabilize the system to simply create a new set of winners and losers.

7.3.7 Step 7: Conduct E-Spot Analysis

The final step in the implementation process is to match the required MTSO resources to MTSO forms of equity from the various stakeholders in the backdrop of the socio-cultural and economic context. The matching is done by literally identifying what form of equity a stakeholder can provide, until all the resources have been met with respective stakeholders, and the roles, responsibilities and benefits for all stakeholders have been identified with accurate timelines. There might be certain resources or stakeholders who might need to be negotiated upon based on the leverage nodes identified in step 6.

7.4 Assessment, Feedback & Conclusion

As has been mentioned before, the E-Spot Model was developed based on practical experiences from the Kenya windmill project described in Chapter 3. For this reason, this project was the first case study developed for the canvas. However, after this study, various student ventures within HESE were analyzed for sustainability using the E-Spot Canvas. During the fall semester of 2010, a HESE class of about 60 students was asked to analyze their projects using the E-Spot Canvas, primarily for the purpose of understanding user interaction and gathering some feedback.

Some key questions/comments/issues gathered were:

- "Identifying all the stakeholders is challenging, especially marginalized stakeholders"—We have experienced this several times, which is why the canvas evolved as a group project for the design team along with on-the-ground partners and other community leaders. Your partners should be familiar with the community and can assist in identifying involved stakeholders.
- "How do I know I have considered all relevant factors for conducting the community assessment?"—You can't; not in one go. It is a iterative process that needs to be carried out on a continual basis so that new information may be learnt over time.
- "I feel it is inappropriate to ask someone much older than me how much money they make. It can be so embarrassing for them."—People in different countries have

different thought processes. Discussing social and economic aspects of one's life is in fact a very common thing among friends in majority of the developing countries. You may not be their "friend", but they will happily discuss this information with you if you genuinely make them understand your reason for seeking such information.

- "I am having trouble with the concept of leverage points. How do I identify them?"—Identifying leverage points is a tricky process. You have to understand your community and the people within it very intricately in order to internalize the various power relationships. Don't expect to be able to spot these relationships on day one. You will have to spend a significant amount of time with the community members to be able to deconstruct them.
- "What is the best approach for conducting the E-Spot analysis?"—There are various approaches to collect information for the various aspects of the E-Spot Canvas that have been outlined earlier. However, the most important and basic requirement of conducting the E-Spot analysis is to do it as a mandatory participatory process with the design team, all stakeholders, various leaders (social, political, religious, organizational, etc.), and community members. When people are involved in a decision process, they feel a sense of ownership towards that process and this is vital to long term sustainability of the venture.

We have received feedback from various professors and other student groups on how the model has assisted the development of their implementation strategy. The E-Spot Canvas is currently being used by groups at Villanova University for various social entrepreneurship projects in the Philippines and Nicaragua. Similarly, groups at Michigan Tech University and

University of Maryland have also expressed an active interest in utilizing the E-Spot Canvas for their engineering projects in different Latin American and Central African countries.

We will be working with the students and professors associated with these projects to gather feedback and validation on the tool and to develop it further with the goal of making it more intuitive and user friendly.

7.5 Future work

Development and validation of the E-Spot Model and methodology is a work in progress. We have completed the design of the preliminary visual canvas (inspired by Osterwalder's business model canvas) for classroom use. The visual canvas and numerous case studies will help refine the methodology and make it more usable by students and faculty members at universities, as well as practitioners. Over the next year, we will be employing the methodology for various infrastructure projects in Kenya, Tanzania, Nicaragua, and India. We are currently studying existing design space exploration tools and business strategy simulation tools with the objective of adapting and integrating relevant tools to build a computer-based modeling engine. In parallel, we are researching visualization techniques to aid the modeling process and visualize the design space and the E-Spot. The modeling and simulation engine will allow technology-innovators and social entrepreneurs to apply the E-Spot methodology to their own projects and identify the optimum equity match between the diverse stakeholders. Our research team hopes that these tools will ultimately lead to sustainable technology ventures which employ organic, participatory approaches for project conceptualization, development, implementation, and assessment. A comprehensive and rigorous learning experience for the engaged students is the desired complementary outcome.

An eventual goal is to develop a software tool that will help automate the equity matching process and provide a visual representation of the equilibrium spot between the stakeholders and required resources.

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