A Taxonomy of Failure Modes of Agricultural Technology Ventures in Developing Countries

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ABSTRACT

Agricultural technologies strengthen and streamline Food Value Chains (FVCs) while improving the lives and livelihoods of smallholder farmers and entrepreneurs. Technologies such as greenhouses, solar food dryers, threshers, grinders, storage, and packaging equipment can make wasteful food systems in developing countries more efficient. However, there are a myriad of technological, infrastructural and operational challenges that hinder the successful design and commercialization of such products. Through a rigorous qualitative analysis of academic literature, online journals, interviews with experts in the field, and our experiences over the past decade, we have devised a taxonomy of potential failure modes during the engineering design, implementation and maturity phases of agricultural technologies ventures. We argue that consideration of these failure modes early in the design process will assist agricultural technology designers and entrepreneurs in avoiding pitfalls later in the venture lifecycle. Each category contains poignant real-life examples to illustrate the complexities of operating in resource-constrained contexts. This taxonomy serves as a foundation for a web-based design tool to inform innovators and entrepreneurs seeking to launch successful agricultural technology ventures in the developing world.

Introduction

Converging global trends such as population growth, desertification, and urbanization have threatened global food security: the accessibility, usability, and availability of food. Despite these and other challenges, the Food and Agriculture Organization (FAO) of the United Nations states that our planet has the capacity to sustain this inevitable growth. This will require maximizing the productivity of land through optimized labor practices, crop yields, water conservation, and waste reduction (OECD-FAO, 2011). It will also entail mitigating two of the most egregious impediments to food security: food waste and loss. Approximately one-third of the world's food produced for human consumption (1.3 billion tons) is wasted by consumers or lost along the supply chain each year (Gustavsson, et al., 2011). In developing countries, nearly 40% of food losses occur after harvest because of premature harvesting, unsafe handling and processing, a lack of processing capabilities, or poor storage facilities (ibid). The utilization of effective processing and storage technologies can save enough food to feed 48 million people (World Bank, 2011).

Food Value Chains (FVCs) encompass a host of activities across six phases: agricultural production, processing, storage, marketing, distribution, and consumption (Contractor and Lorange, 2002). Figure 1 summarizes various examples of agricultural technologies at different phases in the FVC. The adoption and use of such agricultural technologies can strengthen and streamline each phase, resulting in more efficient land use, increased productivity, and a reduction of food waste (ibid). The smallholder market in developing countries is comprised of over 3.7 billion people who live on 8 USD a day or less. Over 70% of these people rely primarily

on agriculture for their livelihoods (World Economic Forum, 2009). Agricultural technologies allow farmers to maximize crop yields and enter lucrative markets (Barrett, 2008).

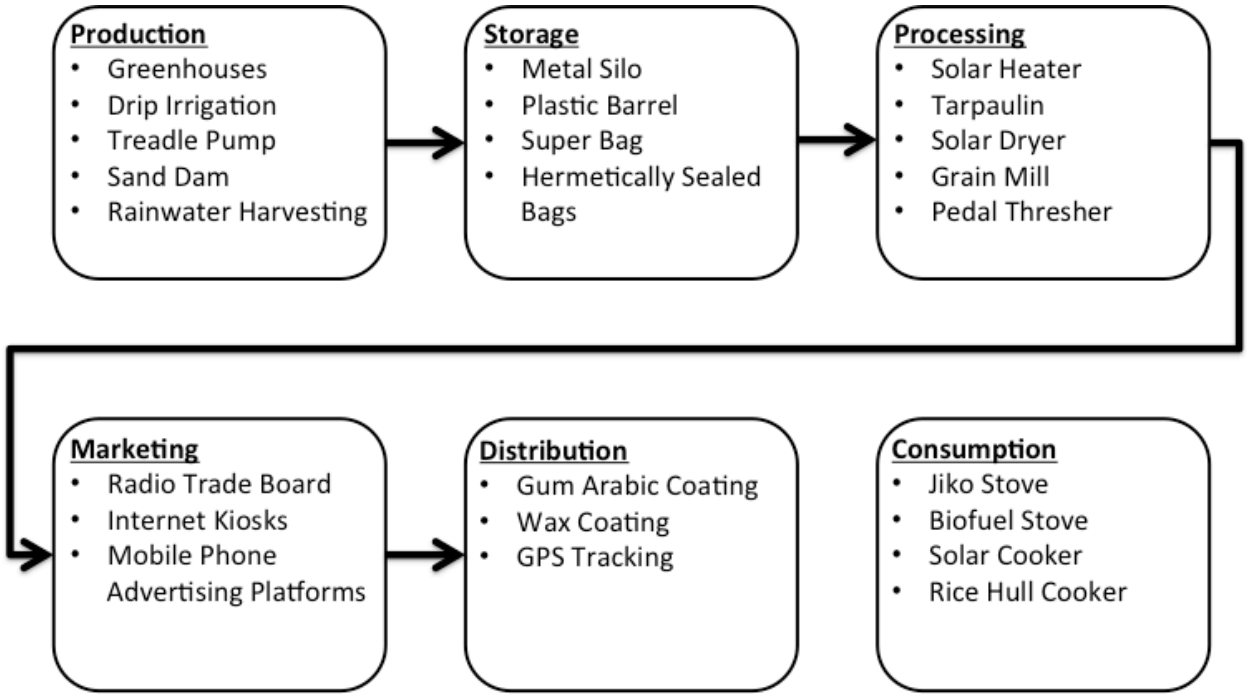

Figure 1. Simplified Food Value Chain with Examples of Relevant Technologies

Currently, such technologies are disproportionately designed for, and used by, large farming operations. This creates a positive feedback loop where farmers with more resources also have exclusive access to advantageous technologies that increase profits (Barrett, Reardon, Webb, 2001). Increased profits allow wealthier farmers to access other assets, such as financial and marketing services, that are generally unavailable to smallholder farmers. Smallholders are in dire need of effective agricultural technologies that can maximize their returns and enable access to other profitable assets and services. Empirical evidence has shown that the lack of access to agricultural technologies is a direct market barrier for smallholder farmers in rural Africa (Barrett, 2008). The amount of agricultural assets has a strong positive correlation with total household income across similar contexts in Burkina Faso, Cote d'Ivoire, Ethiopia, Kenya, Rwanda, South Africa, Tanzania, and by extension, across sub-Saharan Africa.

In essence, successfully equipping smallholder farmers with affordable agricultural technologies can dramatically improve their livelihoods while bolstering the resiliency and sustainability of FVCs. Maximizing the earning potential of smallholder farmers increases the economic potential of over three billion people worldwide. This creates a ripple effect of attractive benefits throughout regional, national, and international markets (Barrett, Reardon, Webb, 2001). These opportunities to effect larger systemic change have not gone unnoticed and a wide range of organizations, from Governments and non-profits to entrepreneurs and large corporations, are designing technology, education, business and policy solutions to empower smallholder farmers. Their motivations span a spectrum of humanitarian concern to entrepreneurial opportunism.

Traditional top-down policy approaches have not succeeded in substantially increasing market participation from smallholder farmers and reducing poverty levels (Barrett, 2008). Similarly, even though a variety of technologies have been developed to improve each phase of the FVC, many of these technologies have failed to reach the target customer segments. Traditional dissemination methods such as donating technologies to developing countries have not been consistently successful since donors often overlook how the technology will fit into the specific social, political, geographic, economic, and cultural context of its users (Polak, 2008). Commercialization has proven to be a more successful method for technology dissemination because of the sense of ownership that customers have in the technologies they purchase and the tangible material value being created for all stakeholders (USAID, 2011). Drawn by the enormous collective purchasing power of smallholders, large corporations, new entrepreneurs and enterprising non-profits are engaging with these emerging markets. The increase in private sector engagement is encouraging because it has the potential to strengthen global food systems by including and empowering smallholders and FVC entrepreneurs.

At the same time, these ventures face enormous technological, financial, organizational, socio-cultural, and political obstacles at every step of their entrepreneurial journey (Contractor & Lorange, 2002). Just like technology ventures in the western world, the majority of such endeavors in the developing world do not succeed in becoming independent economically-sustainable enterprises. Rigorous academic research to support these (small, medium and large) entrepreneurs on the ground is sparse but gradually growing. Previous works have identified abiotic stressors for such ventures and proposed typologies of business models to overcome them with the ultimate goal of accelerating the technology dissemination process (Suffian, et al., 2013). While several studies have articulated challenges faced by entrepreneurs on specific aspects of ventures (e.g. appropriate design, access to capital, manufacturing methods, grassroots marketing) and offered constructive advice, comprehensive studies of failure modes across the entire lifecycle of a venture are hard to find.

"When, why and how do agricultural technology ventures in the developing world fail?" is the question this article attempts to answer. We present major failure modes in the design, implementation, and maturity phases of agricultural technology ventures. These failure modes are derived from narrative review and analysis of several data sources over a three-year period. Data sources include academic literature; practitioner blogs and reports; analysis of operations of 120 successful and failed agricultural technology projects in Africa; interviews with smallholders and FVC entrepreneurs conducted in Kenya, Rwanda, Cameroon and Sierra Leone; interviews with US-based international development professionals; and entrepreneurial experiences over the past decade. This multi-faceted analysis resulted in the creation of a comprehensive taxonomy of failure modes to inform and inspire innovators and entrepreneurs to avoid these pitfalls and build stronger and sustainable enterprises.

Methodology for the Development of the Taxonomy

The nature of this topic restricts, to a large extent, many traditional and common methods of research. Successful ventures often employ an iterative approach to perfect their products and processes; however there is limited literature on the initial iterations that were ultimately unsuccessful. There is even less documentation on ventures that completely failed. Furthermore, there has been virtually no demand for such formal literature. In other words, designers and

entrepreneurs love publicizing their successful ventures and ignore the initial pains they experienced. As far as the ventures that completely failed, the academic community has little interest in their story. Another major reason for this lack of literature is that there is little formal knowledge and discussion on the general topic of Food Value Chains (Gomez, et al., 2011). Such discussions have primarily taken place in more informal spheres, where entrepreneurs with little interest in academia pass along their experiences to likeminded individuals. Therefore, to develop a more thorough taxonomy (and ultimately a more holistic and comprehensive educational tool) we relied on both formal and informal forms of knowledge.

A collection of interviews, personal accounts, and online journals provided us with crucial content to develop our taxonomy. The business and operational models of over 120 agricultural technology projects were articulated using Osterwalder's Business Model Canvas, an analysis of which, contributed to our understanding of failure modes. Formal interviews were conducted with over 500 smallholder farmers, agro-enterprises, entrepreneurs, commission agents, exporters and other FVC players in Kenya, Cameroon, Rwanda and Sierra Leone. These particular countries were implicated because our academic program in Humanitarian Engineering and Social Entrepreneurship (HESE) engages in entrepreneurial ventures related to food security and pre-primary health care in these countries and has an extensive local network. Finally, informal interviews and consultations were conducted with professors and practitioners based at various universities and organizations in the United States. Collecting, analyzing and synthesizing this multi-modal data was a three-year effort that culminated in the development of this taxonomy of failure modes. This taxonomy is not a strict formula, but rather an interconnected web of experiences and knowledge that entrepreneurs can leverage to strengthen their strategies and overcome common and uncommon challenges that inhibit venture success.

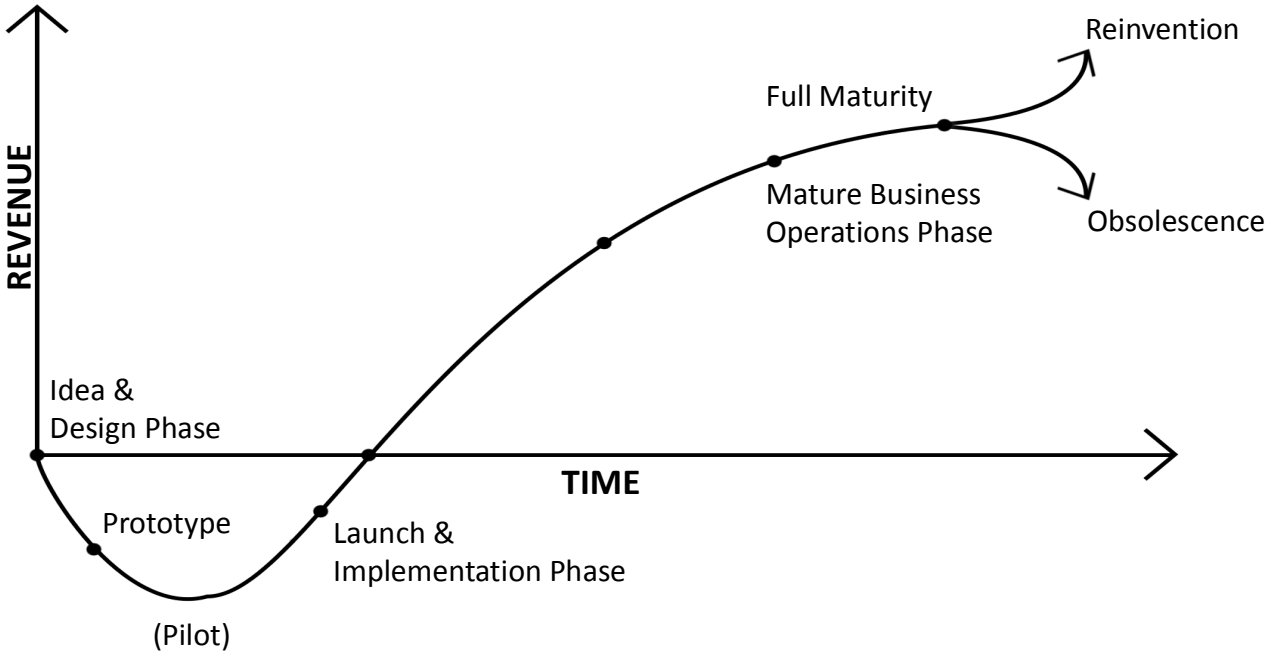

Figure 2. Venture Lifecycle – Design, Implementation, and Maturity Phases. Adapted in part from Norman, 1998

During the analysis and synthesis phases, it became apparent that ventures face very different kinds of challenges across their lifecycle. Hence, the failure modes were categorized across three phases: design phase, implementation phase, and mature business operations phase (Figure 2) (Maley, Perez, and Mehta, 2013). The design phase starts with ideation, encompasses validation and iterative field-testing, and culminates with the launch of the product or service. The implementation phase is the extremely iterative and chaotic journey from product launch to having strong market presence. Finally, the maturity phase focuses on sustaining business operations and ends in either obsolescence or reinvention. The criteria for transitioning into these phases are difficult to pinpoint and depend on case-specific variables. Despite this caveat, the phased approach added structure to the taxonomy and reduced confusion. It further strengthened the premise that, to be successful, ventures must consider challenges across its entire lifecycle at the onset of the venture.

This taxonomy is a dynamic and evolving framework and not a final and irrefutable list. Some of the failure modes are sub-categorized further to illustrate the complexity of the issue. The failure modes have been illustrated with relevant and poignant real-world examples when necessary. While the failure modes themselves are distinct, certain specific examples of a failure can be traced to multiple failure modes. This is inevitable since the failure modes are fundamentally interconnected. Addressing these potential failure modes is not a concrete strategy to ensure venture success. Rather, consideration of the failure modes engenders a better-informed and rigorous design process that can lead to the development of sustainable and scalable ventures.

Failure Modes During the Design Phase

Figure 3 summarizes the failure modes that agricultural technology ventures might encounter during the design phase from conceptualization to validation to field-testing to product launch. Some issues like complexity, manufacturability, designer limitation and usability are related to the designers and the design process while others like culture, context, and failure to meet a need, are more related to the context of the venture.

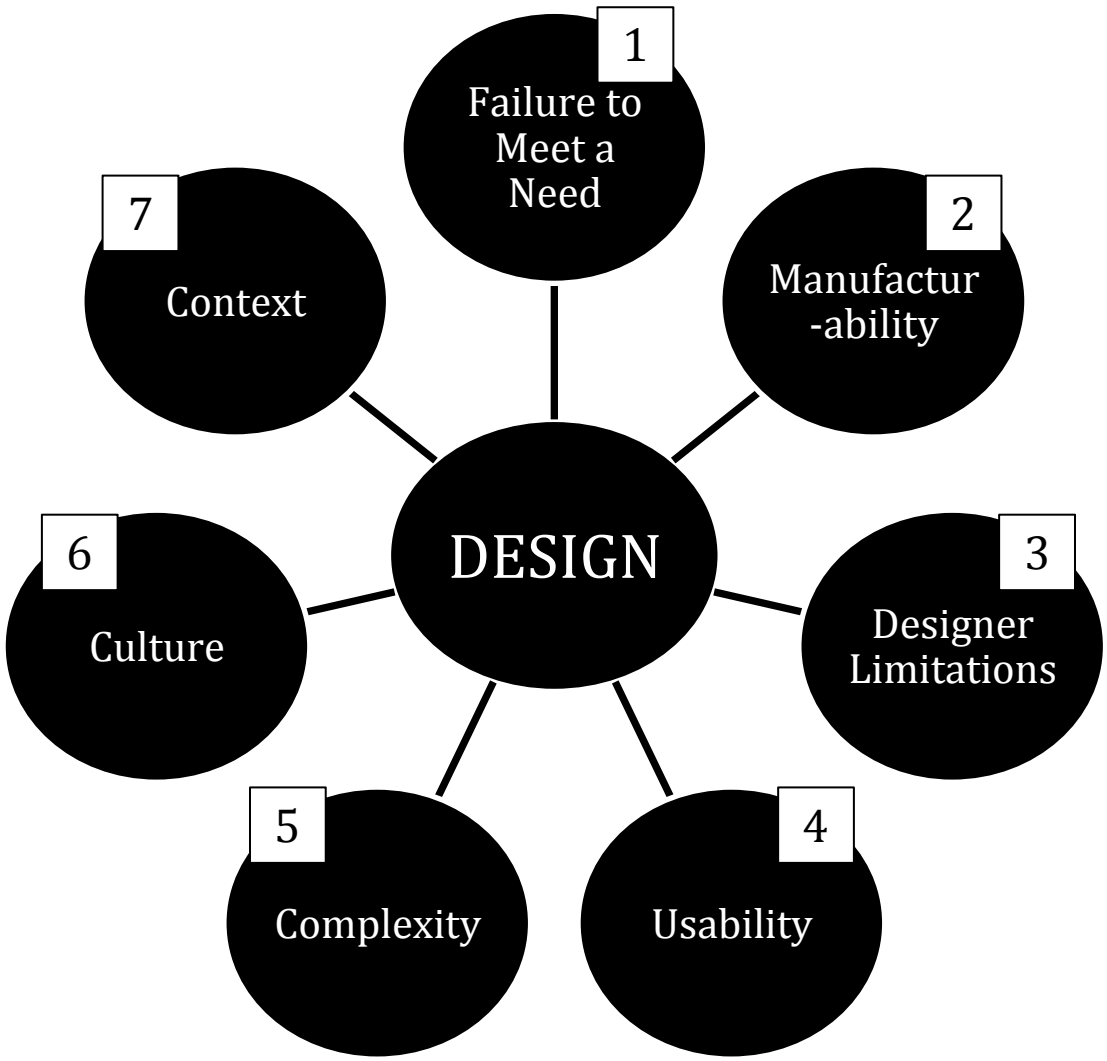

Figure 3. Challenges encountered by agricultural technology ventures during the design phase

1. Failure to Meet a Need: An agricultural technology is designed to perform a specific task and satisfy a specific need. However, there is often a gap between designers' perceptions and the end-user's actual needs. If the end-user is not directly informing the design process, an agricultural technology venture risks designing a product that does not adequately meet the needs of the target end-user. While there are many specific needs not being met, the two most common issues encountered in our study were:
    a. *Failure to Address the Root Problem*: Rather than addressing the root problem, a venture may develop a technology that addresses the symptoms of a larger problem. This exposes ventures to risk from future competition that truly solves the problem. A venture that fails to address the true cause of a larger problem, such as malnutrition in a specific region, could still be considered 'successful' even if this was not their mission. A food-cart, for example, can offer nutritious alternatives in busy town centers. In this case, 'success' is not contingent on solving the complex problem of malnutrition, but rather on providing nutritious alternatives to busy workers.

b. *Poor Return on Investment*: Many agricultural technologies, such as greenhouses or food dryers, require an upfront investment. A technology that requires such investment will need to understand their target customer's purchasing power. A hefty investment is particularly difficult for rural farmers in developing countries. Such customers also have limited access to financing opportunities. Several ventures failed because they did not design their products for specific price targets and reasonable return on investment (ROI) periods.

2. Manufacturability: Manufacturability refers to the specific process by which a product is physically assembled. It is essential for a venture to consider manufacturability early in the design process (Dzombak, Mehta, Butler, 2012). Of several issues related to manufacturability, the three most common points of failure were related to:
    a. *Consistent Manufacturing*: The ability to reliably manufacture a product for the target market is inherent to providing sustainable value. For example, if a venture relies on multiple suppliers for their materials, factors such as cost of production and distribution speed will vary. This variability influences downstream issues such as pricing and trust management. Many ventures fail due to an inability to consistently manufacture and deliver products that their customers expect.
    b. *Lack of Local Spare Parts*: Developing countries often have weak infrastructure systems that make it difficult to acquire spare parts. The availability of local spare parts needed to maintain or repair a product is an important design consideration. If the parts inherent to the design are overly specialized or otherwise difficult to obtain, necessary maintenance may be impossible.
    c. *Lack of Human Resources*: Specific human resources are required to construct, install, repair, or maintain agricultural technologies. If the necessary human resources are unavailable in a given context it will inhibit subsequent implementation and growth. While the workforce can be developed over time, the attrition rates amongst well-trained workers are fairly high.

3. Designer Limitations: Issues ranging from material selection, infrastructure, and repair protocols are examples of the kind of design constraints that are vastly different in developing world contexts. It is imperative that a venture has designers with relevant experience and expertise in designing products for resource-constrained settings. A designer must be able to accurately make (and validate) assumptions about the abilities of, and resources available to, the end-users. Ventures are likely to fail when they employ designers without the necessary experience designing for the developing world. While designers gradually develop this expertise, poorly funded ventures lose valuable time and ultimately fail.

4. Usability: Usability is a measure of the ease with which a product or service can be utilized. During the design process this calculation is based on assumptions concerning the end-user. Ventures that design equipment for specialized fields, (e.g. welding), make certain assumptions about the experiences of their target user in order to gauge the usability of their product. Ventures fail when they make inaccurate assumptions about the capabilities and experiences of their end-users.

5. Complexity: Complexity is a measure of the number of components or connections necessary to make a product work. Simple technology products that provide only the most important features desired by the customers are likely to sustain. The manufacturing or assembly process for the product also needs to be simple enough for local manufacturers lacking formal training to construct with basic tools. Ventures fail if their technology is too complex to be manufactured, assembled, used or maintained by their customers or other stakeholders.

6. Culture: Every culture is unique in various capacities. Designers must determine the compatibility of their technology with the culture of the end-users. We found the most critical considerations to include:
    a. *Lifestyle of End-Users*: Ventures fail if their product is incompatible with the lifestyle of their customers. Some aspects of the end-users' lifestyle will naturally change over time, however it is unrealistic to expect a farmer to make a significant change in order to use a novel product or service. Lifestyles may vary greatly between different cultures and classes within those cultures. This necessitates appropriate and sometimes diverse strategies for a technology to successfully scale across multiple cultures.
    b. *Societal Norms*: Societal norms are group-held beliefs about how members should behave in a given context (Marshall, 1998). The expected behavior of targeted customers (includes gender or age-specific expectations) is extremely valuable information for agricultural technology ventures. Such knowledge can allow a venture to appropriately position their solution for maximum impact.
    c. *Traditional Agricultural Solutions*: Agricultural technology ventures in developing countries typically target end-users who are familiar with relevant agricultural issues and concerns. It is important to consider how the target end-users currently deal with the problem before proposing a new technology. If a traditional solution is adequately addressing the issue, there is no incentive to adopt a new technology.
    d. *Perception of Product*: Various characteristics such as country of origin or the selected materials of an agricultural technology directly affect its perception in a specific culture. For example, a product designed by a German company may have a different perception than a product designed by a Chinese company. The perception of such characteristics varies greatly in different regions and cultures.

7. Context: A designer must understand the parameters within which their product and venture will operate. This entails recognition of the overarching cultural, technological and social constraints and implications of the target market. This comprehensive design category intersects with many of the other categories, but also covers region-specific sub-categories.
    a. *Topographical and Edaphological Factors*: The topography and edaphology of a targeted region directly impacts the viability of a given agricultural technology. While topography refers to the physical contours of a location, the edaphology refers to the how soil influences man's use of land for plant growth (Whittow, 1984). A region's topographical and edaphological characteristics determine the agricultural potential of that location. Thus, agricultural technology ventures must

understand these factors to validate the need, appropriateness, and viability of an agricultural technology in a given context.

b. *Infrastructure*: Infrastructure in developing countries is often a challenge for prospective ventures, particularly in rural areas heavily involved in agriculture (Barrett, 2008). This is a challenge for local farmers who could leverage improved infrastructure to increase the profitability of crop yields. Additionally, the infrastructure greatly affects the efficiency of supply chains. Ventures fail when they do not understand and plan for context-specific infrastructure challenges.
c. *Political Issues*: The type and nature of the political system affects many aspects of agricultural technology ventures. For example, starting a venture in a fledgling democracy like Kenya presents vastly different challenges to that of a venture working in a failed state like the Democratic Republic of Congo. Ventures will fail if they do not understand the relevant political issues, for example the process (or lack thereof) of receiving necessary governmental permissions, taxes, and varying forms of corruption.
d. *NGO Presence & Activity*: Areas without effective NGOs can lack the essential partnerships necessary to facilitate growth and lead to successful implementation. Conversely, too many NGOs in a given region can inhibit scalable impact and also lead to failure. The effect of NGO presence and activity can be anticipated by researching the reputation and impact of local organizations and how the people perceive local NGOs.
e. *Regulatory Frameworks*: Regulatory frameworks can cause a venture to become unrealistic or far too costly. For example, Rwanda's strict regulations on imported plastic constitute a challenge to ventures that needs to import plastic for their product. Regulatory frameworks can also provide ventures with credibility and customer trust if they are not too troublesome.

Failure Modes During the Implementation Phase

Figure 4 summarizes potential failure modes during the implementation phase of the venture: from product launch to establishing strong market presence. The duration of this phase varies from a couple of years to a few decades until the product gets traction and the venture finally has reliable revenues. Challenges during this phase can be classified as either internal or external issues. External issues (1-6) are challenges that occur with stakeholders and entities outside of the organization delivering the product or service. Internal issues (7-12) all occur within the organization, this can be with the product itself or the employees and organization necessary to deliver the product.

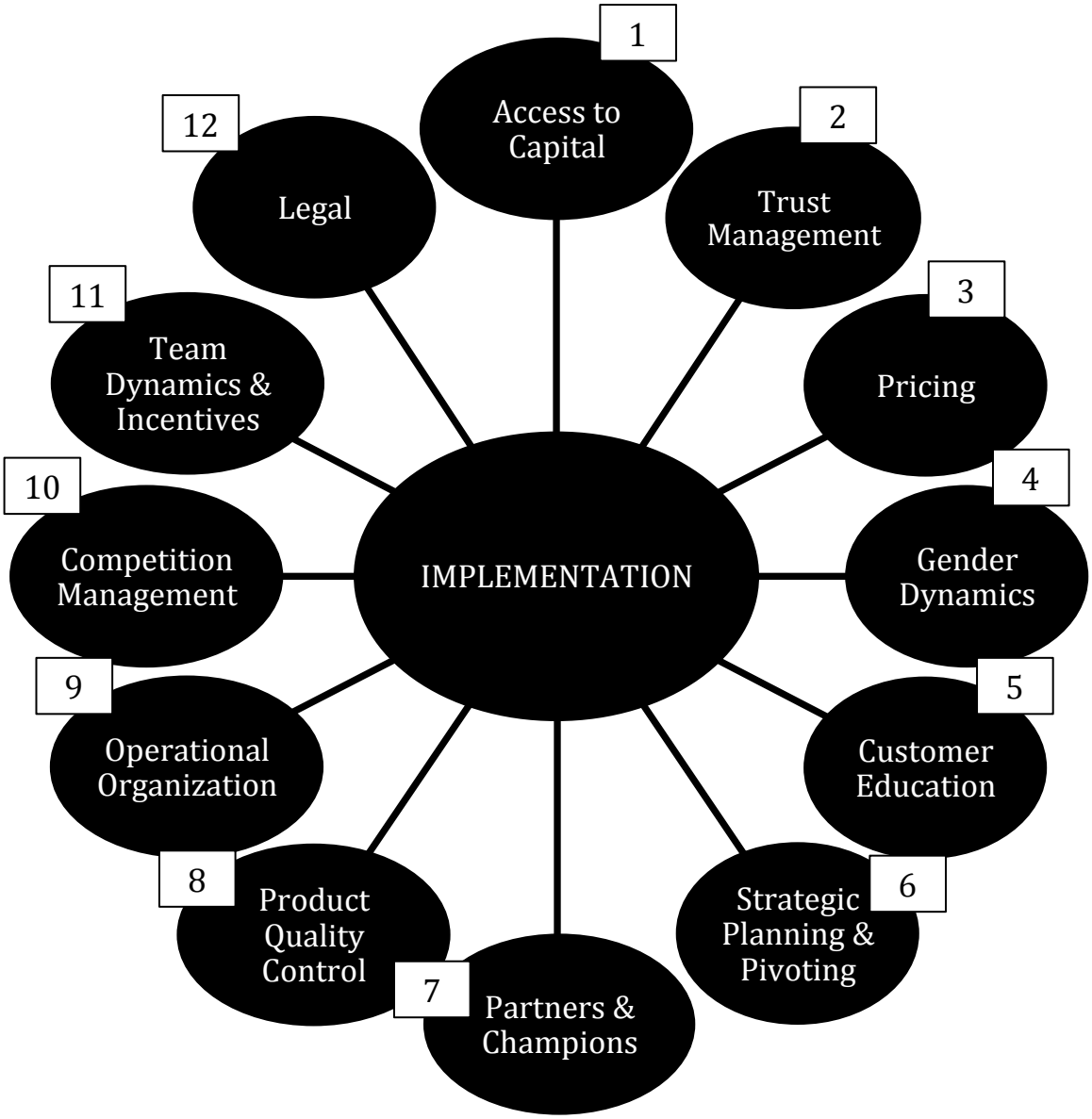

Figure 4. Challenges encountered by agricultural technology ventures during the implementation phase

1. Access to Capital: Ventures need start-up capital. At the same time, their customers also need capital to purchase the products. For both entities, finding financial resources is often difficult.
    a. *Internal Access to Capital*: A new venture must have sufficient capital to cover the start-up and implementation costs. It is important to have an accurate estimation of the necessary costs to bring a venture to the launch stage of the venture lifecycle. It is common for ventures to grossly underestimate the time it would take for them to get traction and have a cash-positive revenue model. In other words, even after product launch, ventures may need loans and equity for several years or even decades. Ventures fail when they are not able to demonstrate impact and continuously raise funds over an extended period of time.

b. *External Access to Capital*: In the developing world, the majority of farmers are smallholders. If a farmer wants to purchase a new agricultural technology to improve their livelihood, they need seed funding. Typical seed funding can come from a combination of personal savings, or from family, friends, and neighbors. An agricultural technology venture needs to develop avenues and channels that will allow their product to reach these farmers. One option is working through the formal financial sector, by building relationships with Savings and Credit Cooperative Organizations (SACCOs), Micro-finance Institutions (MFIs) and other actors in the informal lending space. Ventures fail when they do not establish partnerships that enable their customers to get access to capital to purchase their products.

2. Legal: Ventures encounter a multiplicity of legal issues in formal legal spheres and gray areas when they function in the informal economies of developing countries.
    a. *Informal Legal Issues*: In most developing countries, a large portion of the economy is run informally. Many small businesses and enterprises operate successfully despite remaining officially unrecognized by the government. Formalizing a business tends to be an expensive and time-consuming process which may not be feasible or realistic during the startup phase. However, operating in the informal sector exposes ventures to legal risks as they grow. Every venture has to decide at what point during their lifecycle they must formalize their business. Ventures that formalize their organizations too soon fail when they are unable to pay hefty taxes and bribes and meet stringent import regulations that their informal competitors do not have to. At the same time, ventures that stay informal for too long also run into legal troubles and have the added disadvantage of not having a disciplined and structured entity to make decisions important decisions.
    b. *Formal Legal Issues*: There are specific challenges to consider once a venture is operating in the formal economy. Examples of such issues include: taxes, employment regulations, regulatory frameworks, and intellectual property laws. A thorough understanding of the relevant formal legal issues will assist ventures in avoiding costly litigation. The legal and ethical burden is often higher for ventures operated by foreigners and this increased scrutiny necessitates clear operations from a legal perspective. When ventures need to confirm with the laws and norms of the developing country where they operate as well as a different (often Western) country where they receive funding from, the legal burden is doubled.

3. Pricing: Choosing the optimal price point is a complex task that is influenced by the competitive landscape, local partnerships, and customer perceptions.
    a. *Competitive Pricing*: Agricultural technology ventures must accurately estimate the demand and value of the product in the target market place. Pricing the product too high makes it unaffordable to customers and is a common failure mode. At the same time, products have also failed because they were priced too low and perceived as inferior to other options or approaches.
    b. *Subsidies*: Subsidies provided by government agencies or NGOs can help ventures bridge the gap between the product costs and the price point that their

customers can truly afford. The obvious problem is the development of a black market around the product with customers reselling their products to turn a quick profit. Also, subsidies are not sustainable in the long term. In our study, we encountered ventures that heavily subsidized products to demonstrate demand and boost sales numbers for marketing and fundraising purposes. This created an artificial demand for the product, which was either sold for a profit in different regions or misused, with the ultimate result being the venture's downfall. Similar situations arose when ventures were not able to make the jump from subsidized rates to regular rates for the products because people were expecting to pay the subsidized price.

4. Gender Dynamics: In the developing world, gender roles and norms are often stricter and hence necessitate a greater amount of attention. The roles are derived from cultural perspectives and societal norms and have direct implications on lifestyles. Ventures that do not understand these implications will struggle to develop appropriate dissemination strategies, in terms of marketing, sales and follow-on support. Gender dynamics can also influence financing strategies for ventures. For example, women avoid borrowing money from friends, neighbors and relatives. At the same time, many MFIs prefer to lend to women because of higher repayment rates. Ventures fail when they do not consider gender dynamics in every aspect of the venture, especially during the implementation phases. They must consider not just how men and women will access and operate their product differently but espouse a systemic view of how that product creates value for the users.

5. Customer Education: Some agricultural technologies require a substantial amount of training or experience in order to be operated safely and effectively. Ventures attempting to implement such products must determine what level of training their customers require, and how it will be delivered. Engaging in market research can assist in making a more informed decision regarding the process of customer education. The technology will not be used effectively, and thus not be successfully implemented, if ventures do not adequately educate their end-users. We observed that while ventures tend to do a reasonable job educating their customers when the product is sold, mechanisms for lateral knowledge sharing between end-users that take the specific location and circumstances of the customers into account are rarely developed. This long-term lateral sharing is often more important than the brief operation and maintenance training provided early on.

6. Strategic Planning & Pivoting: Ventures introducing new technology products into a new market must be extremely flexible. Attempts to implement a venture may fail for many reasons. Strategic adjustments to the product, marketing strategy, customer base, or the implementation strategy can make the difference between reaching maturity and failing to get traction for a venture. Ventures fail when they do not continuously assess what is working and what is not and pivot every aspect of their venture until they are successful. We observed numerous cases of ventures or projects that failed when the team refused to change course despite overwhelming evidence that they were on the wrong track.

7. Partners & Champions: Strategic partnerships and champions help ventures to gain the access, exposure, and credibility necessary to successfully implement a technology in a new region. Thorough market research helps ventures identify the initial partnerships necessary for the implementation phase.
    a. *Credibility*: If an agricultural technology venture is implementing a product in a new region, it will require key partnerships to initially reach the market and avoid failure. Such partnerships, particularly if the partner is a local person or entity, can lend crucial credibility to regionally-novel technologies. Such partnerships can take many forms including government support, region-specific business endorsements, support from influential local figures, or even symbolic support from a Western company.
    b. *Community Engagement*: Successfully interacting with the local community at a grassroots level can establish a market presence for a given product. Foreign companies especially require early community engagement to proactively define the perception of the venture. Ventures that have brick and mortar locations with approachable representatives for potential customers can talk to tend to be better received, particularly in rural areas.

8. Product Quality Control: Reliable manufacturing and distribution channels are two areas that can potentially compromise quality control, particularly in areas with poor infrastructure. Without consistent product quality, ventures are unable to build the trust in their brand that is crucial for word-of-mouth marketing and increased sales. During our study, we came across a wide range of quality challenges: locally-assembled products that failed because of worker training and discipline issues, imported agricultural implements shipped from abroad were of excellent quality the first time but of poor quality in subsequent containers, or poor quality of raw materials that compromised the final product.

9. Organizational Structure: Ventures that lack clear roles and responsibilities for their employees often fail to operate effectively on the ground. Ventures must identify specific needs and hire the personnel capable of effectively implementing the venture's business strategy. Poor organization complicates the decision-making process and decreases the odds of successfully navigating the implementation phase.

10. Competition Management: Agricultural technology ventures encounter many situations while implementing a solution in developing countries where intellectual property protections are not respected or enforced. In such situations, competition management often involves overcoming challenges from counterfeit designs. During our study we found examples of many ventures that were unable to understand the competitive landscape of their technology and were eventually completely marginalized in the marketplace by cheap knockoffs. A common approach of the counterfeiting companies was to provide higher sales commissions to retailers. Several small companies and vendors recounted instances of customers coming with workmen to study and photograph the technology product and then making it themselves in carpentry or metalworking shops.

11. Team Dynamics and Incentives: Intra-team dynamics directly impact the effectiveness of every organization. This takes on particular importance for ventures implementing agriculture technologies in the developing world. Such ventures typically involve a diverse set of stakeholders with different levels of engagement and responsibility. In order to optimize team dynamics a venture has to evaluate how each employee contributes to the venture and what the incentives are for this involvement. We came across a very large number of projects initiated by westerners that failed because the team either had internal conflict or a key member left.

12. Trust Management: Managing trust between internal and external stakeholders is paramount in developing countries, particularly for ventures championed by people perceived as outsiders. Ventures fail when they do not develop strategic partnerships to build and maintain trust in their brand and technology amongst the stakeholders. Without this trust, customers will not be interested in an unfamiliar product with no local credibility and the venture may fail during the implementation phase. Trust is paramount in all personal and professional undertakings because farmers as well as micro-entrepreneurs prefer to work with people they know and trust at the expense of reduced profits or new customers.

Failure Modes During the Maturity Phase

The following categories, summarized in Figure 5, fall under "maturity phase challenges." These failure modes generally occur between an established market presence and before either obsolescence or reinvention (see Figure 2). Many of the issues have similarities to challenges during the implementation phase. However, a category such as legal issues has a different definition depending on the level of maturity of a venture.

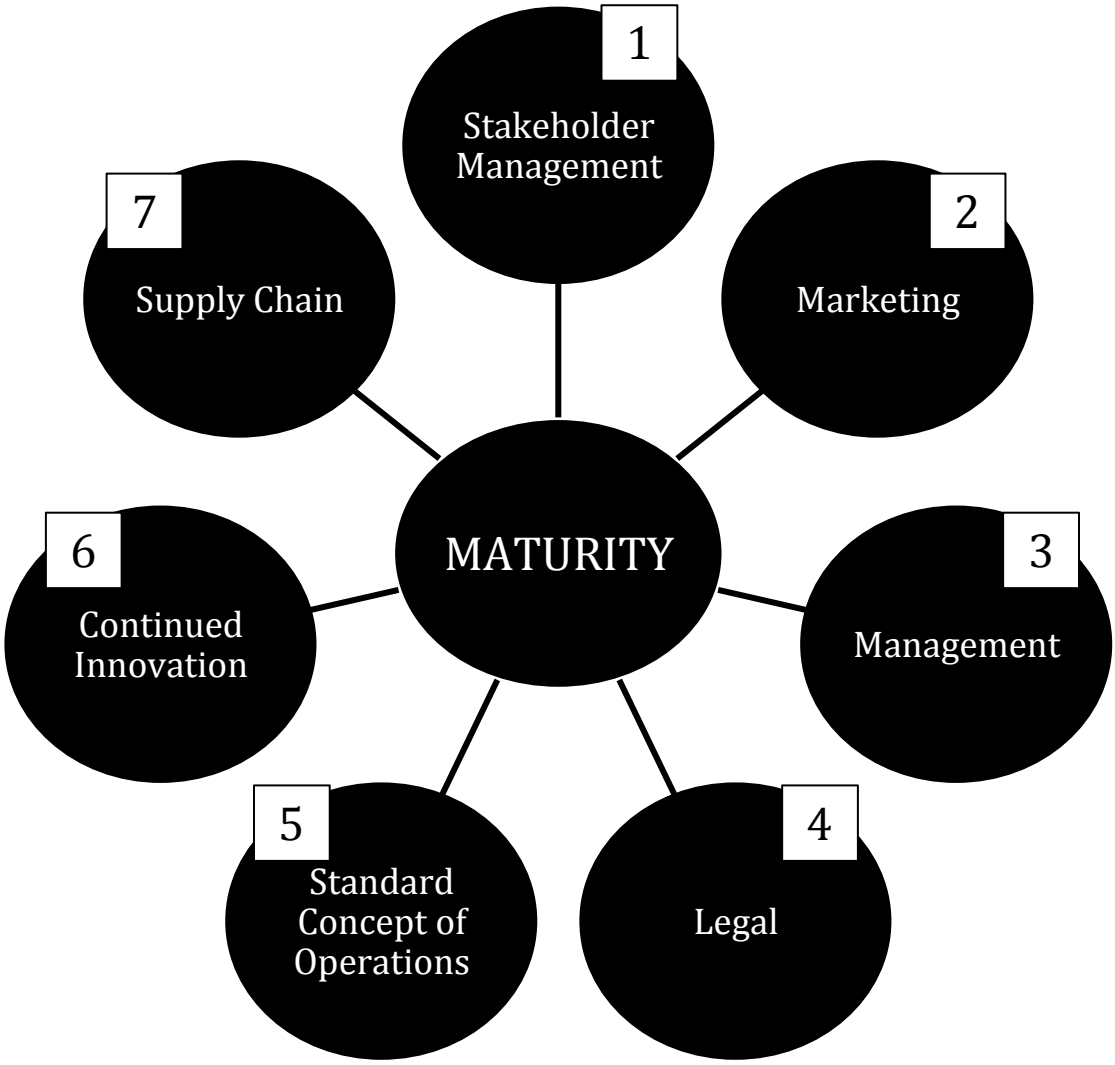

Figure 5. Maturity Phase Challenges – Based on the venture lifecycle found in Figure 2.

1. Stakeholder Management: Important decisions must be made regarding the engagement of various stakeholders as a venture evolves. While certain stakeholders may be required during start-up and implementation, they may be unnecessary, or even a distraction, at advanced phases of the venture. Conversely, expansion of business operations may necessitate additional stakeholders with specific expertise. Ventures fail when they don't reevaluate their stakeholder relationships on a continual basis and take a practical and strategic approach to building and maintaining relationships.

2. Marketing: Marketing can be particularly difficult when the majority of targeted end-users live in rural areas. Non-traditional platforms and channels must be leveraged to consistently reach relatively obscure customer segments. Ventures that rely on traditional Western marketing techniques (e.g. billboards on busy roads or television ads), often fail to reach their customers in rural areas. Furthermore, marketing strategies like these are costly and potentially fatal to a venture if it does not receive a significant return on the investment. We found that, for many successful enterprises, marketing was intricately connected to developing relationships with customers and empowering them. For

example, traditional credit cooperatives were much more successful than MFIs because they employed business development officers whose job was helping communities organize themselves and save money. Ventures failed because they did not proactively cultivate their markets with practical, long-term and customer-centered approaches.

3. Management: The initial management structure used by a venture may not be ideal as the venture moves into the maturity phase. If a venture is seeking to expand to new regions or reach a different market it should consider the constraints of their current structure and employees. Ventures failed when they did not candidly reevaluate the goals, team strengths and dynamics, and management styles necessary to sustain and grow the organization. We saw numerous cases of failure when the visionary entrepreneur did not empower a management team who was familiar with working in the specific context.

4. Legal: In all likelihood a venture in the maturity stage will be operating in the formal economy. This type of operation offers different set of challenges compared to legal issues during implementation. As a venture matures and becomes more profitable, regulatory scrutiny tends to increase and ventures need to stringently follow local laws related to employment practices, product quality, etc. In developing countries, there is often a disconnect between local laws and norms that present additional legal challenges to companies. These legal challenges are compounded when ventures have legal roots in multiple countries and must abide with conflicting regulations or stringent regulations in western countries that reduce profits in developing countries.

5. Standardized Conception of Operations: The concept of operations (ConOps) explains exactly how a venture will create, deliver and capture value. This concept of operations inevitably changes and fluctuates significantly during the design and implementation phase. At the point of maturity, however, a venture should have enough knowledge and information to standardize this process. Standardized operations allow for sustainable and reliable products and processes. This process of converting tacit knowledge on every aspect of the venture into clearly documented procedures can be instrumental as the venture evolves and experiences employee turnover. Ventures often failed because they were unable or unwilling to document and standardize this process.

6. Continued Innovation: A mature venture will attract external entities attempting to replicate its success. Continued innovation allows a venture to maintain and improve its market share and enhance its competitive advantage. As is the norm in the Western world, ventures failed when they did not prioritize research, development and continual innovation.
    a. *Increase Venture Efficiency*: Once in the maturity phase, a venture should have enough data and experience to optimize their process of value creation and delivery. This will maximize productivity and thus profitability. We found that several ventures failed because they were not responsive to evolving customer needs and did not strive to periodically improve their products and processes.
    b. *Strategies for Growth*: A venture in the maturity phase should continuously research new market opportunities for growth and revenue diversification. Such opportunities may not have been feasible earlier in the lifecycle, but a mature

venture can take advantage of experience and credibility to further expand operations. In the agricultural sector there are often additional complimentary activities that ventures could perform, for example agriculture production technologies and processing technologies (i.e. canning or desiccation after production). Ventures that do not strategize for continued growth and innovation consistently lose market share to new competition willing to innovate.

7. Supply Chains: Agriculture technology ventures operating in the developing world inherently face unique and complicated supply chain challenges. For example, typically the majority of the target market lives in rural areas with poor infrastructure. Such constraints affect the manufacturing, assembly and distribution of products. Ventures fail when they are unable to overcome supply-chain disruptions and have backup plans if certain vendors fail to deliver parts.

Conclusion

Agricultural technology ventures face different kinds of challenges across their lifecycle, across the design, implementation, and mature business operations phases. This article discusses common failure modes of such ventures in the developing world. The taxonomy of potential failure modes presented in this article has been validated with feedback from academic experts and practitioners. At the same time, there will always be emergent failure modes and this taxonomy will always remain a work-in-progress. This study strengthens the premise that in order for ventures to be successful, they must consider downstream failure modes at the onset of the venture. Through this work, we are seeking to begin the process of translating valuable incidents of failure into practical and useful lessons. This taxonomy forms the foundation of a web-based example-centric educational tool for technology developers and entrepreneurs. Consideration of these challenges and the lessons learned across the venture lifecycle engenders a better-informed and rigorous design process. This can lead to the development of sustainable and scalable agricultural technology ventures that can deliver the impact they are envisioned to have.

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