FAILURE MODES FOR 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 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.

Introduction

Converging global trends such as population growth, desertification, and urbanization have threatened global food security, i.e., the accessibility, usability, and availability of food. Despite these and other challenges, the Food and Agriculture Organization (FAO) of the United Nations has argued that our planet still has the capacity to sustain this inevitable growth. This will require maximizing the productivity of land through optimized labor practices, crop yield, water conservation, and waste reduction (OECD-FAO 2011). It will also entail mitigating some of the most egregious impediments to food security, namely 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 and are caused by premature harvesting, unsafe handling and processing, a lack of processing capabilities, or poor storage facilities (ibid.). If effective processing and storage technologies could be utilized to prevent these losses, the saved food would have the potential to feed 48 million people (World Bank 2011).

Food Value Chains (FVCs) are comprised of several processes divided into the following phases: agricultural production, processing, storage, marketing, distribution, and consumption (Copley et al. 2013). The adoption and use of agricultural technologies strengthen and streamline these processes, resulting in more efficient land use, increased productivity, and a reduction of food waste (ibid.). There is a robust smallholder market comprised of 3.7 billion people who live on $8 USD a day or less. Within this market segment, 70% rely primarily on agriculture for their livelihoods (World Economic Forum 2009). In response to this demand, a myriad of businesses, non-profit organizations, NGOs, and academic programs have emerged to develop agricultural technologies appropriate for this market. Figure 1 summarizes various examples of such technologies at different phases in a food value chain.

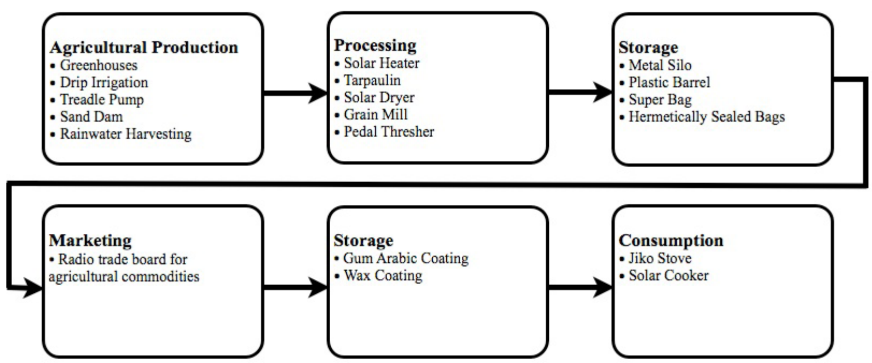

Figure 1. Simplified Food Value Chain with Examples of Relevant Technologies

Successfully engaging the smallholder market with affordable technologies bolsters the resiliency and sustainability of their FVCs. Innovative technologies that not only implement appropriate business models but also accurately assess relevant abiotic stressors improve livelihoods while fostering food security (Suffian et al. 2014). Along with this opportunity come unique challenges, which have hindered entities from getting their technologies to the targeted end-users (Contractor and Lorange 2002). These challenges span the various phases of a venture's lifecycle, including systems design, implementation, and maturity business strategy (Maley, Perez, and Mehta 2013). Agriculture technology ventures have to successfully navigate all three phases of their lifecycle; missteps in any of the three can result in failure. If an agricultural venture designs technology that is too expensive or too complex for their target market, it will never reach a business maturity phase. Similarly, if such a venture designs an effective agriculture technology but fails to develop key partnerships and recruit champions who will help implement the technology, it will never successfully reach the market. Finally, a business can navigate both the design and implementation phase well, but struggle with managing growth and ultimately fail to achieve economic sustainability.

Why and how do agricultural technology ventures fail? This article presents an analysis of major failure modes in the design, implementation, and maturity phases of an agricultural venture. We employ academic literature, online journals, interviews with experts in the field, and our experiences over the past decade to illustrate frequent missteps of a venture en route to maturity. The analysis results in the creation of an initial taxonomy of failure modes. The ultimate goal of this taxonomy is to develop an educational tool that can be used to inform students, engineers, and entrepreneurs about common mistakes and challenges. This tool will reinforce the importance of a "triple-helix" approach by integrating implementation and business strategy from the beginning of the design process. This article begins with an explanation of the venture lifecycle and a methodology for the development of the taxonomy. We will then explore challenges during the design, implementation, and business phases and conclude with the next steps forward for this project.

Phases of a Venture Lifecycle

Designers often view the ideation and initial design activities as completely separate from the rest of the venture lifecycle. Figure 2 shows how the venture lifecycle is a continuum and how each phase influences the subsequent phase.

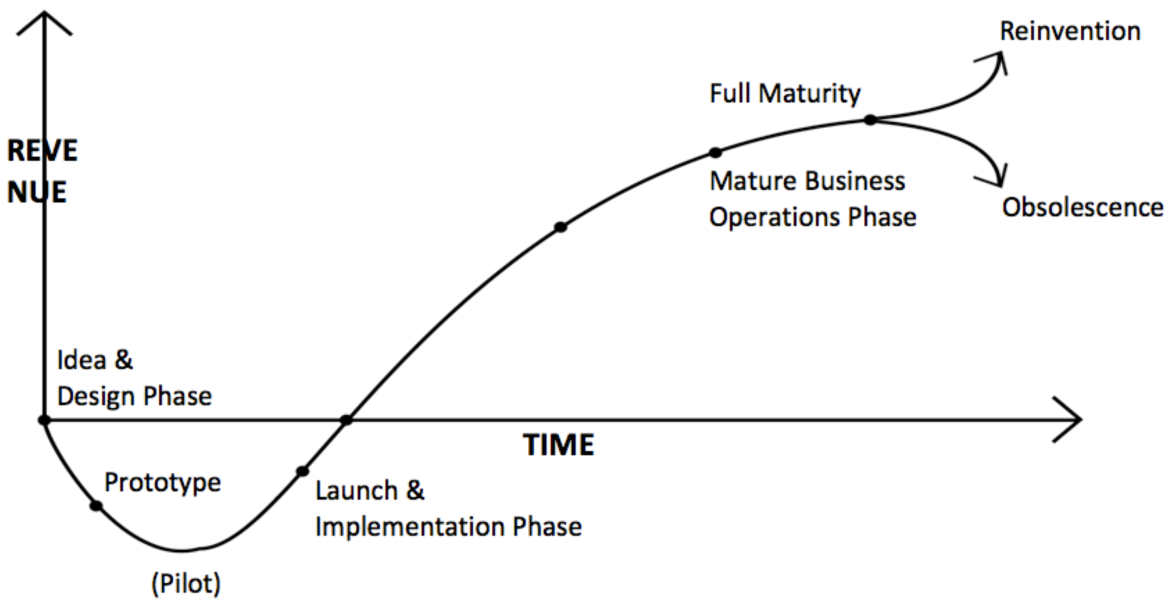

Figure 2. Venture Lifecycle: Design, Implementation, and Maturity Phases Adapted in part from Norman, 1998

The venture lifecycle shown in Figure 2 is comprised of three stages: the design stage, starting with original ideation and value proposition development; the implementation phase, taking the venture from launch to a strong presence in the market; and finally the maturity phase, which ends in either obsolescence or reinvention (Maley, Perez, and Mehta 2012). The criteria for transitioning into these various phases are potentially difficult to identify and depend on case-specific variables. For the last decade, the Humanitarian Engineering & Social Entrepreneurship (HESE) program at Pennsylvania State University has gained valuable experience on starting technology-based social ventures in diverse world regions. This experience has exposed various shortfalls of engaging in a piecemeal approach to engineering design, business strategy, and implementation strategy development for technology-based social ventures. A more comprehensive and integrated approach that engages in the concurrent and iterative design of the product, its concept of operations, and the implementation strategy and business strategy, is needed (Maley, Perez, and Mehta 2012). An understanding of the failure modes for technology ventures can inform this integrated design process.

Methodology for the Development of the Taxonomy

The nature of this topic restricts, to a large extent, on many traditional methods of research and development. Successful ventures often employ an iterative approach to perfect their processes; however there is limited literature on the initial, ultimately unsuccessful iterations. There is even less documentation on ventures that completely failed and never found sustainable success. Furthermore, there has been virtually no demand for such formal literature. In other words, designers and entrepreneurs love publicizing their successful ventures and ignoring the initial growing 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 (FVCs) (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 like-minded individuals.

Therefore, to develop a more thorough taxonomy (and ultimately a more holistic and comprehensive educational tool), we are compelled to rely on both formal and informal sources of knowledge. A collection of interviews, personal accounts, and online journals provided us with crucial content to further develop our taxonomy. These more informal sources of knowledge often confirmed or otherwise emphasized assertions found in the small amount of academic literature on the topic. We have found that relevant experiences (both formal and informal) have been just as valuable as academic speculation. The kinds of ventures in which we are interested do not exist in a purely academic setting, but rather a dynamic and constantly evolving developing world context. Thus, any relevant taxonomy or framework on ventures in this context must also be dynamic and capable of evolution. Our taxonomy is not a strict formula, but rather a web of experiences and knowledge that entrepreneurs can utilize to overcome common and avoidable failure modes. A multidimensional and transdisiplinary conceptual framework is needed to study FVCs in the developing world and this is what we have sought to create (Gomez et al. 2011).

In order to accomplish this, we began compiling and analyzing examples of failure throughout the burgeoning field of social entrepreneurship. Understanding the variety of factors that often lead to failure will allow future entrepreneurs to avoid these common pitfalls. We began by reviewing formal academic literature on FVCs and examples of social entrepreneurship failure. Additionally, we leveraged the valuable decade of experience in developing startup ventures in resource-constrained regions. This included experiences from current HESE members and former HESE members who continue to work in international development. Furthermore, our experience has connected us with other programs, companies, and nonprofits that have experienced or witnessed relevant failure. We also used more informal sources, such as blogs and personal accounts, to develop a more thorough and realistic taxonomy.

In the subsequent section, we have aggregated various common challenges and failure modes that agriculture technology ventures encounter. We have attempted to use hypothetical examples, derived from real-world experience and our research, to illustrate each challenge. It is by no means a final and irrefutable list. This represents the initial synthesis of our research to date and, as stated above, we consider it a dynamic and evolving framework. We will continue the refining process until each failure mode is thoroughly validated. We will then begin to develop a comprehensive and interactive educational tool. Each of the following challenges is followed by a short example of the challenge. These examples are derived from our research and are based on real-life situations. Additionally, none of the following categories are exclusive in any sense. They are all interconnected with one or more of the other categories. There is more than one way to consider and categorize a failure mode. The categories of failure within our framework represent a synthesis of the various research inputs grouped into logical categories. Furthermore, there are potentially multiple ways of overcoming the following categories of venture failure. We do not contend in this analysis that there are concrete strategies to achieve success. Rather, we argue that consideration of the following failure modes will produce a more informed design and thus a venture that is more likely to be sustainable.

Challenges: Design Phase

The following categories, summarized in Figure 3, fall under "design phase challenges." These failure modes generally occur between design ideation and the launch of the product or venture (see Figure 2). Issues such as complexity, manufacturability, designer limitation, and usability are directly related to the physical design process. Culture, context, and failure to meet a need are more closely related to the area of implementation.

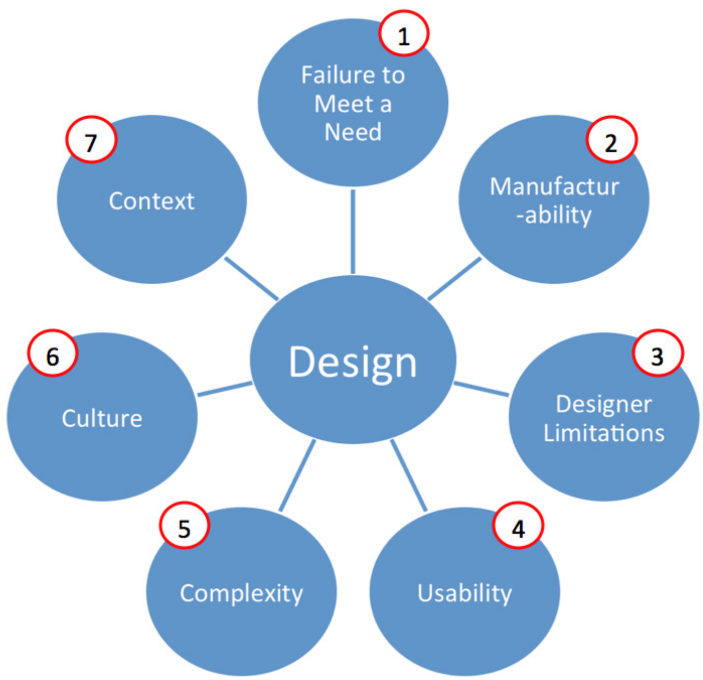

Figure 3. Challenges encountered by agricultural technology ventures during the design phase.

1. Failure to Meet a Need: An agriculture technology has a specific need it is intended to meet. However, there is often a significant gap between Western designers' perceptions and the end-user's actual needs. There is also often a difference of opinion about the perceived value of the agriculture technology. If the end-user is not directly informing the design process, an agriculture technology venture risks designing a product that does not adequately meet the needs of the target consumer.

   Ex: A venture designs a food storage container that is inexpensive. However, there was an insufficient amount of research done. The product is never implemented because the targeted region already has effective, indigenous methods of food preservation and storage that do not require the technology created.

2. Manufacturability: Designers must consider the eventual manufacturing of their agriculture product for successful implementation and scale. Manufacturing issues such as overhead costs, local availability of necessary machinery and tools, consistent manufacturing capability, and other related issues directly impact the viability of any agriculture technology venture. While it may be desirable to use local manufacturing, many developing countries lack the necessary infrastructure to make such a decision feasible. It is essential for a venture to consider manufacturability early in the design process (Dzombak, Mehta, and Butler 2012).

   Ex: A team develops a low-cost greenhouse for the developing world; the design calls for bamboo attachments, with strict design tolerances, that are produced locally to keep the price low. The bamboo and the manufacturing capability are unavailable in the target market: East Africa. While this was a good design, without consistent manufacturing capability, the venture cannot establish itself.

3. Designer Limitations: Design for the developing world has specific and unique constraints. Issues ranging from material selection, infrastructure, and maintenance are examples of different kinds of design constraints. It is imperative that a venture has designers with relevant experience in this realm of design. A designer must be able to accurately make assumptions about the abilities and resources available to the end-user. A designer without the necessary experience is inherently ill-suited for designing for the developing world.

   Ex: A team interested in a solar-dryer design for West Africa hires a designer who does not have relevant experience in design for resource-constrained environments. The resulting design calls for materials that are prohibitively expensive because they must be imported.

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. Businesses that design equipment for specialized fields, such as welding, make certain assumptions about the experiences of their target user in order to gauge the usability of their product. Likewise, agriculture technology ventures must make accurate assumptions about the capability and experiences of the target end-user.

   Ex: A venture designs mobile-based software for crop cycle, water, fertilizer, and land management to enable farmers in the developing world to optimize production. Desiring accurate predictions, the designers opt to include user-defined variables and tweaks to optimize each individual experience. However, the end users have little familiarity with such mobile applications and even less knowledge of the meaning and function of the many inputs.

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 low-skilled labor to manufacture using basic tools.

   Ex: A design team develops and begins marketing a complex irrigation system for the developing world. The technology works well when properly assembled. However, the design is difficult to assemble correctly without extensive training. Often the technology is installed with missing or incorrectly installed components leading to inefficient irrigation, clogs, and leaks. The product develops a reputation for being inefficient and inconsistent and subsequently never scales up because it is too complex for assembly and maintenance.

6. Culture: Any technology that is not culturally acceptable is inherently unsustainable. Issues under this umbrella include the roles and lifestyle of the end-user, societal norms, and traditional agriculture solutions. It is also important for the designer to recognize that every culture is dynamic in various capacities. Designers must determine the compatibility of their technology with the culture of the end-user.

   Ex: A team designs a treadle-pump solution for a small town in Namibia. The local leaders decide to prohibit use of the pump because it causes the women (who are responsible for fetching water) to move their hips in what is deemed an inappropriate manner. Thus, the technology is inherently unsustainable and never reaches the maturity phase.

7. Context: A designer must understand the parameters within which their product and venture can 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 micro-issues that do not fully constitute their own failure mode.

   Ex: The greenhouse a design team has developed calls for a specific plastic only commercially available in Israel. They have been targeting Rwanda, but have not considered the country's strict plastic import regulations. The venture becomes unrealistic and far too costly.

Challenges: Implementation Phase

The following categories, summarized in Figure 4, fall under "implementation phase challenges." These failure modes generally occur between venture launch ideation and establishment of strong market presence (see Figure 2). 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 physical product itself or the employees and system directly delivering the product.

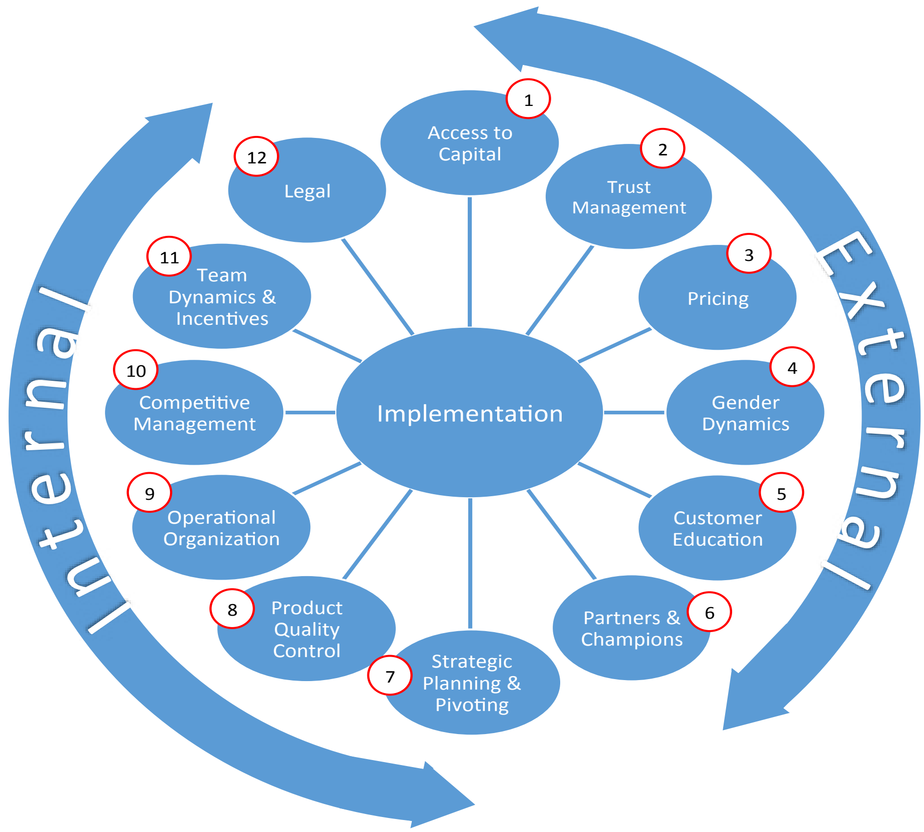

Figure 4. Challenges encountered by agricultural technology ventures during the implementation phase

1. Access to Capital: In the developing world, the majority of farmers engage in subsistence farming. If a farmer in these resource-constrained environments wants to purchase a new agriculture technology to improve his or her livelihood, they need seed funding. Typical seed funding can come from a combination of his or her own savings, and from family, friends, and neighbors willing to assist the farmer. An agriculture technology venture needs to develop avenues and channels that will allow their product to reach these farmers. One option is working through the financial sector, by building relationships

with saving and credit cooperative organizations (SACCOs) and other micro-finance institutions (MFIs). Another option is to incorporate an intermediary link into a supply chain and not sell directly to the end-user. Rather, identify NGOs and non-profits that will buy said product and sell it to the end users for a fraction at the cost to increase accessibility.

Ex: A venture has developed an affordable greenhouse design that can be built at a fraction of the cost of typical commercial greenhouses. They hope to reach poor farmers that live on only a few dollars a day and actively lift them out of poverty. The venture has difficulty getting the technology to the poorest of the poor because they do not have enough money to purchase the product despite the price point despite is lower than typical greenhouses and the return on investment is short. The venture needs to develop strong partnerships with financing organizations to reach their target market.

2. Legal: A thorough understanding of the distinction between formal and informal legal issues will greatly assist any venture in the developing world. 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 growth occurs. Every venture has to decide at what point during their lifecycle will they formalize their business.

   Ex: A solar dryer begins building and selling small amounts of affordable solar-dryers in a small rural community in Kenya. It is completely operating in the informal sector in order to keep startup costs at a minimum. The design begins to gain some traction and the venture begins receiving inquiries from large food drying enterprises in Nairobi wishing to purchase the dryers in bulk. Upon realizing the business in unrecognized by the government, the large companies end negotiations in order to avoid legal risks.

3. Pricing: Choosing the optimal price point is a complex task when designing agriculture technologies for the developing world. Smallholder farmers in these contexts often have a negligible amount of discretionary income. At the same time, a venture has to ensure that relevant markets perceive the appropriate value for their products.

   Ex: A greenhouse venture overprices their product in an attempt to maximize profits and perceived value. Ultimately the social goals of helping small-scale farmers are unrealized, as they cannot afford an overpriced greenhouse. Intermediary options, such as local non-profits and NGOs, are reluctant to purchase the greenhouses because they feel they can help more people by investing in cheaper technology products.

4. Gender Dynamics: In the developing world context, gender roles and norms are stricter and hence necessitate a greater amount of attention. The roles are derived from cultural perspectives and societal norms. Analysis of these factors reveals many relevant trends, particularly for agriculture technology ventures.
   For example, in sub-Saharan Africa, the vast majority of smallholder farmers are women. Furthermore, in many societies these women do not handle the finances for their household. Such dynamics directly impact the best way for an entrepreneur to implement and scale an agriculture technology venture.

Ex: A team attempts to develop a farming device that plants seeds quickly and efficiently. They spend a great deal of capital on a marketing campaign that targets adult males. However, the vast majority of small-scale farmers in the developing world are women. This leads to an ineffectual marketing campaign and the waste of precious resources.

5. Customer Education: Some agriculture technologies require a significant amount of training or experience in order to be operated safely and effectively. Ventures attempting to implement such technology must determine what level of training their product requires. Engaging in market research can assist in making a more informed decision.

   Ex: A venture is seeking to implement affordable greenhouses in West Africa. The construction and operation of the greenhouses requires a significant amount of training. After conducting a few educational workshops the venture licenses their design to a company based in Ghana. The company hires local handymen who are not trained adequately on the construction process or on the operation of the greenhouse. After a few initial sales the greenhouse company gains a reputation for being difficult to use and poorly built.

6. Strategic Planning & Pivoting: Ventures of any kind need to have a great amount of flexibility to enhance their probability of success. This is especially important when introducing a new technology to a region. The initial attempt to implement a venture may fail for any number of reasons. Subtle adjustments to the product, marketing strategy, customer base, or the implementation strategy can make the difference between reaching maturity and failing to successfully implement a venture.

   Ex: As a team begins implementing a solar dryer design in Kenya, they experience trouble reaching the original target audience of government agencies and relevant NGOs. Instead all of the sales come from wealthy hobbyists from Nairobi. They do not attempt to capitalize on this unexpected interest and continue unsuccessfully marketing to organizations and agencies.

7. Partners & Champions: Any venture needs strategic partnerships and champions in order to gain the access, exposure, and credibility necessary to successfully implement a technology to a new region. Such partnerships can take many forms including government support, region-specific business endorsements, and employment of influential locals. Identifying the appropriate partnerships involves garnering essential information about how the targeted region operates.

   Ex: An affordable greenhouse venture in Cameroon attempts to introduce unfamiliar technology and processes related to their venture. They fail to identify and target an opinion leader who can influence the community at large to trust the team and the technology. Once the team returns home no one is interested in continuing to use the product.

8. Product Quality Control: A venture must establish trust and credibility in order to successfully implement a solution in the developing world. A resource-constrained environment is a significant challenge to ensuring product quality. Reliable manufacturing and distribution channels are two areas that can potentially compromise quality control, particularly in areas with poor infrastructure.

   Ex: A new rainwater harvesting system venture was featured in a major East

African newspaper. They are now getting orders from all over East Africa at a greater volute than expected. They quickly hire local handymen all over the region to try to satisfy all of the orders. The new handymen lack sufficient training and now the venture cannot ensure standard quality control and it is damaging its reputation across East Africa.

9. Organizational Structure: The structural organization of a venture is a major decision during the implementation phase. The delegation of roles and responsibilities dictates how effectively a venture will operate. This process also involves identifying specific needs and the capable personnel. One of the specific areas that need to be addressed for agriculture food ventures is how will the venture operate on the ground, how autonomous are representatives and employees, how decisions are made, and how progress is monitored and assessed. An effective on-the-ground presence is essential during the implementation phase and great care should be taken in determining how this is structured.
   Ex: A solar dryer venture, based in East Africa, adopts a strict, hierarchical organizational structure. On-the-ground sales persons are assigned precise time and location schedules to maximize the number of potential customers reached. This approach conflicts with the local norms and perceptions of the value of time and personal interactions. The sales members object to this approach but their concerns are not transmitted up the chain of command, resulting in reduced sales and disgruntled employees.

10. Competition Management: The competitive landscape is much different in a developing world context compared to the Western world. For example, agriculture technology ventures operating in the United States primarily rely on patents to protect the intellectual property involved in the technology. There are certain situations in the developing world where this form of intellectual property has essentially no value. Ventures implementing technologies in such areas need to adapt sensible strategies to cope with this landscape. If a newly introduced technology is successful, the venture should expect counterfeit designs to start being produced. Additionally, interest from larger agriculture businesses will also be inevitable.

    Ex: A team begins implementing their food dryer technology in Ghana successfully. As the venture begins to gain popularity, it attracts interest from counterfeit designers and large agro-businesses. Eventually a large Indian company makes a significant investment in an attempt to dominate the market. The product operates the same but costs less because the Indian company has a better supply chain. The team has to pull out of Ghana because they can no longer make a profit in this region.

11. Team Dynamics and Incentives: The intra-team dynamics directly impact the effectiveness of any 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. It is essential for sustainable ventures to narrow gaps between value and incentives.

    Ex: A cellphone-based system designed to alert farmers of climate and weather events is conceived in a prominent university located in the North East United

States and is launched in Haiti. While three of the team members are excited about this decision to invest scarce resources in Haiti, two other team members conclude that Haiti is not a good place to pilot this. They decide to exit the project and start a new company that will launch a similar product in a different country.

12. Trust Management: Trust between stakeholders is a key component of successful implementation for agriculture technology ventures. Stakeholders include everyone working within the venture, as well as other outside entities that interact with the system. Potential external stakeholders include the consumers, strategic partners, and sources of venture funding.

    Ex: Actions by all stakeholders in a greenhouse venture affect trust-based relationships and venture success. If promises are not kept and expectations are not met, partners will decline further involvement and investment in the venture. Once trust is broken, workers will not be eager for employment from the company and customers will not demand greenhouses if they find the venture management or products unpredictable. Ultimately, if a lack of trust hurts partnerships, negative perceptions of the venture and product will decrease sales and the integrity of the brand will suffer.

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

Challenges: 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.

1. Stakeholder Management: Important decisions must be made regarding the engagement of various stakeholders as a venture matures. While certain stakeholders may have been required during start-up and implementation, the same stakeholders may not be necessary in a later stage. Conversely, expansion of business operations may necessitate

additional stakeholders with specific expertise. It is important to constantly assess the necessary level of engagement of all stakeholders.

Ex: A rainwater-harvesting venture identifies local handymen in various regions throughout Kenya in an attempt to handle dispersed orders more efficiently. They pay them an average day's wage. As orders roll in, the venture is finding that these handymen are not responding quickly because they do not have enough incentive to drop whatever small task they are currently working on since the wage is merely the average. They attempt to rectify this error by increasing their pay but their reputation has already been damaged because of unfulfilled and backlogged orders.

2. Marketing: Marketing agriculture technology ventures is a complex task in the developing world. The task can be especially difficult when the majority of end-users may live in extremely rural areas. Traditional methods of promotion may not be effective in this case. Optimal platforms and channels must be identified and leveraged to consistently reach relatively obscure customer segments.

   Ex: A greenhouse company in Tanzania is attempting to market their product in major cities to maximize the budget allowance for promotion. The majority of their potential users live in rural areas and rarely travel to the city. The marketing promotion fails to produce enough sales to make it worthwhile.

3. Management: The initial management structure used by an agriculture technology venture may not be optimal when the maturity phase begins. If a venture is seeking to expand to new regions or reach a different market it should consider the constraints of their current structure. A realistic re-evaluation of venture goals, team dynamics, and current positioning will greatly assist in this process.

   Ex: A venture attempts to use a horizontal management structure, which discourages the traditional hierarchal format. There is no effective way to settle disagreements and this leads to some partners feeling marginalized and offended when decisions do not go their way.

4. Legal: In all likelihood a venture in the maturity stage will be operating in the formal economic sphere. This type of operation offers unique challenges compared to legal issues during implementation. As a venture becomes more mature and profitable, regulatory scrutiny may increases. In the maturity phase, a venture must ensure that it is operating within a formal legal structure; otherwise, it becomes vulnerable to resource-draining litigation.

   Ex: A greenhouse venture using greenhouse-grade plastic in their design must adhere to updated environmental regulations imposed in Rwanda. This makes access to necessary plastic difficult to obtain, as only a few companies hold the rights to import greenhouse-grade plastic in the country. The venture must decide to purchase plastic from their competitor, or attempt to obtain the importation rights, which is a long and expensive process.

5. Standardized Conception of Operations: A concept of operations directly explains exactly how a venture will create and deliver 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. A standard

concept of operations allows for more sustainable and consistent value creation.

Ex: As a greenhouse venture continues to expand, they must maintain their brand by standardizing their concept of operations. From the time a customer purchases a greenhouse, all levels of the company should follow an order and process. This guarantees that a greenhouse is assembled, delivered and constructed efficiently and uniformly. If the growing venture cannot maintain a standard concept of operations, it will be impossible to reinforce a positive brand identity.

6. Continued Innovation: A mature venture will attract external entities attempting to replicate and copy their success. This could lead to dangerous vulnerability to loss of market share to imitators. One strategy to avoid this is through continuous research and development and exploration of potential new market segments. Continued innovation allows a venture to maintain their market position and protect their competitive advantage.

   Ex: A profitable solar food dryer venture decides against further research into even more affordable and effective solar panel technology. Within a year a new competitor enters the market using this improved technology with a significantly lower price point. After the new company establishes a market presence the original company can no longer compete with obsolete solar panel technology.

7. Supply Chains: Agriculture technology ventures operating in the developing world inherently face stiff supply chain issues. Often times the majority of the target market live in rural areas in regions with poor infrastructure. A mature venture should constantly seek to diversify and streamline its supply chain, both to lower expenses and to inoculate against supply-chain disruptions.

   Ex: A venture has begun to sell greenhouses in Rwanda and is now receiving orders from eastern Uganda. They agree to sell to these areas, however fail to identify a local manufacturer and distributer. The overhead costs become too great and they begin to lose money on the expansion project. They decide to pull out but their brand reputation is damaged from the unsuccessful foray.

Conclusion

The categories listed above represent common trends found during our research into failure modes of agricultural technology ventures in the developing world. However, almost every category contains many different sub-categories. In the next step of this project, we intend to further explore and flesh out the complexities within each category. This will result in a more rigorous and comprehensive analysis. Despite a large and connected community of relevant academics and entrepreneurs, there is currently a deficiency of literature concerning the development of sustainable ventures in a developing world context. Through this work, we are seeking to bridge this gap and begin the process of translating valuable experience into practical and useful lessons.

This paper represents the first steps in exploring common failure modes for agricultural ventures in the developing world. We have presented the culmination of our initial research, which serves as the foundation for further development, refinement, and research. We intend to send this manuscript to a myriad of entrepreneurs, academics, as well as individuals currently working in the field. The feedback we receive will directly inform the next step: development of an educational tool that can be used by students and prospective social entrepreneurs. By outlining common challenges and failure modes, we can assist the next generation of problem-solvers to avoid frequent pitfalls. A more informed design process will lead to a greater prevalence of sustainable enterprises in the developing world. Our ultimate goal in designing a comprehensive education tool is to maximize the potential impact of new technologies and start-up ventures. This is certainly a work in progress and we are constantly adapting and refining our parameters and taxonomy to more accurately represent the most relevant challenges to the dynamic field of international development.

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