Managing operational capabilities in startup companies

by

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M.S. Mechanical Engineering (1995)
S.M. Engineering and Management (2013)

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Abstract

Hundreds of papers exist on entrepreneurial marketing and finance, whereas capabilities for operations get far less attention. Furthermore, much of the literature in operations management addresses challenges of companies in stable environments, leaving entrepreneurs with little theoretical or practical guidance on operations strategy. As a result, many entrepreneurs focus their efforts on value creation: marketing, product development, lead generation, and conversion. Ironically, extreme focus on value creation might represent a trap, whereby a company fails not because of a poor value proposition or bad marketing, but because of an inability to scale up and deliver value for perhaps an outstanding, innovative new product or service. In over a dozen case studies written during the past four years, we have found numerous examples where the development of operational capabilities was a determining factor for success or failure in entrepreneurial firms. We study the effect of timing of introduction of operational capabilities on market success as a function of firm's value proposition. We provide case evidence on the challenges and opportunities of building operations capabilities in entrepreneurial firms and we construct theoretical and testable models for assessing when and why entrepreneurs should invest sooner, or later, in operational capabilities.

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1. Introduction

As they are told to do in countless books (e.g., *Lean Startup* (Ries, 2011), *Disciplined Entrepreneurship* (Aulet, 2013)), many entrepreneurs focus their early efforts primarily on product development and customer acquisition. Although seemingly ironclad, this strategy may sometimes represent a trap, whereby a company fails not because of a poor value proposition or bad marketing, but because of an inability to scale up and deliver value for perhaps an outstanding, innovative new product or service.

Our research addresses this tension with a theory and model catalyzed by a set of longitudinal and cross-sectional cases we have developed over several years. In addressing the challenges, practices, and issues related to developing operations capabilities in entrepreneurial firms, we find certain circumstances when a direct causal relation exists between timely investment in operational capabilities and market success of a start-up company. Using model simulations, we isolate core dynamics and illustrate specifics of common modes of failure in resource constrained startup companies. With our model, we also explore boundary conditions and discuss implications to guide entrepreneurs and academicians.

By suggesting and exploring a novel theoretical framework to identify optimal strategies of investment decisions in a startup environment as a function of underlying value proposition, we contribute to academic literature in such fields as entrepreneurship (addressing the question of decision priorities and determinants of success of a startup), strategy (exploring the performance trajectories of different strategies under various conditions), and operations management (finding optimal allocation of resources in a constrained environment). Accompanying simulation model is fully documented and can be augmented and calibrated for a specific industry or a company, and we hope to induce a stream of follow-up research that aim at testing and improving our falsifiable theory by using novel datasets. We return to case studies to illustrate the theory and illuminate lessons. By providing practical policy recommendations

and suggesting optimality conditions, we guide entrepreneurs to evaluate their strategic decisions with minimum computations using simple and clear assumptions directly following from their business models.

In the following sections, we motivate our research agenda (section 2), review relevant literature (section 3), introduce our research questions (section 4), discuss the data and summarize our case studies, leading to the development of the model (section 5), present the model (section 6) and its results (section 7), summarize our conclusions and recommendations (section 8), and discuss future work (section 9).

2. Motivation

To be successful, a company needs to: (1) create value and (2) deliver value, i.e. create capabilities to deliver the value to consumers using its own resources or through value chain partners. In a startup environment where often "cash is oxygen," multiple needs must be carefully managed to support transformation from limited exogenous funding to eventual endogenous positive cash flow. The fragile landscape of uncertainty about value proposition often tips the trade-off between investing in value creation and value delivery towards refinement of the product or service and its market, and postponing the development of operational capabilities farther down the road. For some companies this might be a reasonable strategy; others might be better off making concurrent investments in operations and value creation. These decisions are made more complex because some features of the investment trade-offs involve long delays in the system – adverse or favorable outcomes may only be discovered long after early choices were set. Short-term concerns may sometimes lead managers to shift priorities away from building operational capabilities. Well-intended actions can backfire and managers can become hostages to their own aspirations.

The importance of these choices is hard to overstate – for most startups, there is no time or money for "plan B." We address the question of how should the time and resources of a startup company be balanced between value creation and value delivery. As discussed in the next section, numerous authors cite the need to create, capture, and deliver value, but many de-emphasize the details of value delivery and operations capabilities.

3. Literature

Van de Ven, Hudson, & Schroeder (1984) identified three lenses to study startups – entrepreneurial (characteristics and backgrounds of the founding individuals), organizational (planning and initial development processes of a new firm), and ecological (the industry as a whole with total population of firms as unit of analysis). Gartner (1985) defined four major dimensions of new ventures – characteristics of individuals, environment, organization, and processes, and suggested using this framework to consider all patterns of new ventures creation process. Shane & Venkataraman (2000) reviewed research on entrepreneurship from different fields and offered a synthetic framework that looks at the entrepreneurial endeavor from existence to discovery and exploitation of entrepreneurial opportunities, where decisions at each stage are affected by information asymmetries of the markets, existing institutional forms of exploitation, and individual characteristics of aspiring entrepreneurs.

Synthesizing and regrouping these frameworks, we find it useful to consider the existing literature in the following categories: (1) Entrepreneurship Strategy, which is further subdivided in (a) Organizations and Environments, considering strategic planning, resources and capabilities, and marketing, and (b) Individuals and Networks, exploring characteristics and social capital of entrepreneurs, and their embeddedness in organizational networks; and (2) Operations Management that discusses specific issues related to the capabilities of interest to

our work. In what follows, we offer systematic review of the existing literature in these dimensions.

Entrepreneurship Strategy

The entrepreneurship strategy literature builds on the core strategy literature, including the foundational work by Albert Humphrey at Stanford Research Institute who created *strength-weaknesses-opportunities-threat* analysis, Porter (1979), who identified *five forces* shaping competition dynamics in an industry, and Wernerfelt (1984), who coined the term *resource-based view* and explored how firms' resources generate competitive advantage. In addition, Barney (1986, 1991) offered four empirical indicators to evaluate resources and introduced the concept of *strategic factor market* where such resources can be acquired. Dierickx & Cool (1989) discussed *time compression diseconomies* and underscored that key strategic resources must be accumulated and should be non-tradable, non-imitable, and non-substitutable. Further, Teece, Pisano, & Shuen (1997) suggested that resources and competencies should be managed in response to changing environments using *dynamic capabilities* that become a source of competitive advantage. Turning to individuals, the foundation for research of *individuals and networks* was laid by Allen (1970) who studied informal relations and communication patterns in teams and showed their effect on project performance, and Miller (1983), Van de Ven et al. (1984) and Bird & Jelinek (1988) who described entrepreneurs as leaders whose *personal characteristics* directly influence business issues.

Organizations and Environments

Starting from the beginning of the entrepreneurial cycle, the literature explores the role of *planning activities* by new ventures, with some scholars arguing for, and some arguing against, strategic business planning in entrepreneurial firms. Duchesneau & Gartner (1990) found that successful firms spend more time in *planning activities* and use outside professionals and advisors, although many startups don't have a formal business plan. Matthews & Scott (1995)

studied antecedents of planning activities and suggested that startups engage in planning activities more often that other types of organizations in the absence of environmental uncertainty. Delmar & Shane (2003) found that "business planning reduces the likelihood of venture disbanding and accelerates product development and venture organizing activity." While some scholars provide support for unconditional advantages of business planning before marketing activities or talking to customers (Shane & Delmar, 2004), others find that planning should be contingent on the context, such as cultural and founding environment (Gruber, 2007; Brinckmann, Grichnik, & Kapsa, 2010). Yet others (Karlsson & Honig, 2009), found that even when entrepreneurs wrote business plans "as part of a symbolic act to gain legitimacy for their actions", they "gradually and without exception, ... lost interest in their plans, and stopped updating them."

Carter, Gartner, & Reynolds (1996) argue that tangible commitment is more valuable than planning. They suggest that the "critical factor for differentiating individuals who start businesses from those that do not involves action rather than planning, or "doing" rather than "thinking" about it" (the highly popularized "Lean Startup" (Ries, 2011) promotes this view.) Carter, *et al.* conclude that entrepreneurs "who do not devote the time and effort to undertaking the activities necessary for starting a business may find themselves perennially still trying, rather than succeeding or failing" and that successful entrepreneurs actively "looked for facilities and equipment, sought and got financial support, formed a legal entity, organized a team, bought facilities and equipment, and devoted full time to the business." Recent work by Chwolka & Raith (2012) attempts to reconcile these arguments by focusing on ex-ante decision making value of planning activities. In the discussion of the role of planning activities scholars take a high level view. While it is quite clear that planning activities of startups (including business planning) might and should include such specifics as timing and resources allocated to product

development and operational capabilities, the literature doesn't discuss the details we consider important in this work.

Looking at a new venture from *resource-based capabilities* perspective (Wernerfelt, 1984; Grant, 1991; Peteraf, 1993; Chandler & Hanks, 1994), many scholars studied the effect of resource endowments and resource acquisitions on strategy and performance of startups. (Brush, Greene, & Hart, 2001) argued that entrepreneurs often don't have the necessary resources to begin with, and have to build a resource base gradually. The authors categorize resources as human, social, financial, physical, technology, or organizational, and propose two frameworks that consider resources based on their complexity, applicability, and relevance to value creation. At an abstract level, the resource-based view addresses the issues we find to be of interest (the accumulation of resources crucial for delivering a product or a service), but our focus is on addressing these issues at a more micro, fine-grained level, discovering the conditions dictating the need for and acquisition strategy of required resources.

In the entrepreneurial *finance* literature, economists King & Levine (1993) argued that better financial systems allow for better selection of entrepreneurs by diversifying risks and providing effective external financing for high quality innovative projects. New ventures academics Åstebro & Bernhardt (2003) argued that while funding in general has positive effect on survival of firms, non-bank loans have stronger effect, possibly due to self-selection against commercial banks. Cassar (2004) demonstrated that size of the firm is an important factor in attracting new financing and Eckhardt, Shane, & Delmar (2006) argued that financing is a two-stage process where founders are self-selecting into fund-seeking pools based on their perception of market conditions, thus limiting choice for investors. Kerr & Nanda (2009) emphasized the importance of considering both size and technological novelty of a startup when connecting external financing and entrepreneurial success. Finance scholars Hellman & Puri (2000) showed that VC financing is associated with faster time to market by looking at innovators vs. imitators and

concluded that innovators are more likely to receive VC funding. Jeng & Wells (2000) in a global study across 21 countries considered venture capital investment cycles and found that IPO activity reinforces VC investments by demonstrating exit strategy for venture capital and thus making the process of funding tightly coupled to entrepreneurial projects.

Research from different fields considered *human and financial capital* as mutually connected determinants of startup performance. Sociologists Bruderl, Preisendorfer, & Ziegler (1992) argued that number of employees and amount of invested capital are the most important factors affecting the trajectory of a startup. Management scholars Cooper, Gimeno-Gascón, & Woo (1997) confirmed that both human and financial endowment determines failure or success of a startup, Chandler (1998) found that they are partially substitutable, and economists Montgomery, Johnson, & Faisal (2005) clarified that while human capital is important to create a business, the financial capital is necessary both to establish and to run a startup. Entrepreneurial researchers Davila, Foster, & Gupta (2003) connected VC funding and employee pool dynamics, discovering that number of employees increases before and immediately after VC funding round, thus considering funding event as a signal to employees about the quality of a startup. While financial and human capital is extremely relevant to our work, the literature doesn't fully address the issue of limited resources and optimal allocation strategy when it comes to defining the investment policy in early startups.

Innovation and technology has been a focal point of entrepreneurial studies. New product strategy study (Meyer & Roberts, 1985) looked at product development activities and concluded that founders "required a clear perception or vision of how to achieve distinctive functionality in a sequence of future products utilizing the initial key technology." Eisenhardt & Tabrizi (1995) bucketed existing research in compression model (emphasizing predictability when there is no or low uncertainty) and experiential model (focusing on iterations and improvisation) of product innovation, and using empirical study found that product development is a hard to plan,

uncertain, and iterative process where "flexibility and improvisation are essential." Thomke (1998) emphasized the importance of experimentation strategy that combines different learning modes to reduce cost and time. Brown & Eisenhardt (1995) reviewed a broad range of literature and suggested a model of product development integrating rational planning and execution, external and internal communication, and disciplined problem solving that emphasizes the role of project team and leaders, senior management, and suppliers and customers to achieve financial success of a new product. The focus of this literature on innovation doesn't discuss the conditions under which an innovation might fail due to insufficient ops capabilities, thus requiring more balanced approach that we are aiming at exploring in this work.

Initial *organizational and material resources* of startups can be greatly augmented through *partnerships and alliances* with companies in their value chain or in the same industry or through social embeddedness in networks (Uzzi, 1996). Cooper (1985) looked at the earliest relations a startup might be involved in – with an incubator company and other organizations in the same incubator – and found that incubators affect geographical location of startups after they leave by shaping their earliest connections – with suppliers, partners, and early customers, and facilitate balanced team formation through access to broad range of key skills, although this relations seem to be less salient for nontechnical firms. Eisenhardt & Schoonhoven (1996) considered alliance formation of entrepreneurial firms and argued that strategic needs and social opportunities are important, but noted that to get new resources firms have to have some resources to start. Higher rates of alliance formation were found to be in environments with emergent markets, competition, and innovative strategy – when firms were in most vulnerable positions and when alliance formation would provide access to additional resources. (Gulati, 1999) confirmed the reinforcing nature of alliance formation as a function of network resources that provide informational advantage (and are linked to firms' performance) and which value is defined by firm's location in the network, initial experience, and prior membership in other

alliances. Stuart, Hoang, & Hybels (1999) investigated alliances of new ventures with large and influential companies and found that they reinforce perceived quality of a startup through status transfer and lead to higher performance by providing better access to resources. Lee, Lee, & Pennings (2001) argued that while links to venture capital companies are directly associated with higher performance of startups, links to other companies, venture networks, universities, and government have no direct effect in the absence of internal capabilities. Lechner, Dowling, & Welpe (2006) studied several types of networks and found that networks that facilitate relations with market leaders and direct competitors, and provide access to informal marketing information are positively associated with firm's performance. Recognizing the importance of proper partnership, the literature doesn't explore the nature of activities and specific goals that are to be fulfilled with the help of external resources and through alliance formation.

Entrepreneurial orientation (EO) as a separate focus (see Lumpkin & Dess, 1996) was studied by many scholars, yet the definitions of EO are not always consistent. Rauch et al. (2009) defined EO as "entrepreneurial strategy-making processes that key decision makers use to enact their firm's organizational purpose, sustain its vision, and create competitive advantage(s)." In a composite review of 14,259 companies from 51 studies they showed positive correlation of entrepreneurial orientation and financial and perceived nonfinancial indicators of performance. Scholars of EO are mostly focused on abstract concepts such as risk-taking and innovativeness and are not specific enough to differentiate between design and delivery of value proposition.

Considering importance of *marketing* for new ventures, Lucas (1994) advocated for concurrent marketing and technology strategy where market needs pull technology and technology becomes an enabler for marketing. Knight (2000) echoed this idea in global context and empirically confirmed that marketing activities need to inform technology acquisition, since marketing responds to the demands of buyers and allows for proper adaptation of products to

local market needs and standards. Many scholars considered marketing as the core of entrepreneurial behavior, arguing that marketing and entrepreneurial orientation consisting of many strategic and tactic activities are closely interconnected. The discussion mainly evolved along effectiveness of formal and informal marketing processes, as well as applicability transactional and relational marketing to startups. Stephenson (1984) argued that main problem for new ventures is to get sales and claimed that poor sales are mainly due to the lack of formal marketing activities, such as promotion technique and market research and strategy, while firm rely too much on informal channels. The author suggested new firms should allocate more resources to strategic planning with focus on sales and marketing. Brush (1992) showed that new manufacturing ventures are actively engaged in well-planned market scanning activities through personal and indirect sources. While marketing a product or a service and information acquisition about its perception is definitely an extremely important aspect of building a successful company, the literature doesn't consider the challenges associated with producing and delivering freshly minted value proposition, assuming full elasticity of supply.

Individuals and Networks

In addition to organizational and environmental issues, scholars have studied individual characteristics of founders, their intentions, experience, knowledge, communication patterns, and social networks. Miller (1983) suggested to categorize firms as simple (small with centralized power), planning (bigger and with more formal control), and organic (adaptive to the environment and with open communication patterns) and showed that personal characteristics of leaders are important in simple organizations. Van de Ven et al. (1984) conjectured that "competence, confidence, imagination, and commitment are ... core characteristics of successful entrepreneurs" and empirically confirmed that founders' education, experience, control and risk management, clear business idea, and personal investment are significantly related to startup success. Bird & Jelinek (1988) created a star model of entrepreneurial

intentions and described entrepreneurs as leaders with substantial freedom of choice and ability to structure resources and focus on business issues, being agile, flexible, and influential.

Beginning from seminal work by Allen (1970) who studied communication in teams and found that informal relations and physical location are important factors of success of R&D facilities much has been written about social capital and the role of communication and networks in the success of an emerging organization. Hansen (1995) confirmed that size of the entrepreneurial set (number of people who participate in the startup formation), its interconnectedness, and frequency of communication are directly related to the positive organizational performance in early years. Ostgaard & Birley (1996) surveyed 159 English entrepreneurs and confirmed the effect of networks on company performance through facilitated access to critical resources. Eisenhardt & Schoonhoven (1996) found that previous experience and connections of top management affect the rate of alliance formations and suggested that strong social position of management teams is important to the formation of such alliances. Shane & Stuart (2002) considered social capital of founders as determinant of VC funding and predictor of startup success and showed that direct and indirect relationships with venture investors represent an important resource for a startup company that increases likelihood of securing external funding and going through an IPO process. Gilmore et al. (2006) showed that personal networking of SME managers increases marketing sophistication and efficiency within a channel threatened by large established players.

To summarize, the Entrepreneurship Strategy literature of Individual characteristics of entrepreneurs and their Networks spends a great deal of time focusing on personal traits (both innate and acquired) and communication patterns, yet falls short of specific details of how such traits and connections are to be used to navigate the company from ideation to exploitation. The Organizations and Environments literature provides rich set of strategic insights and recommendations related to management of resources and capabilities needed for value

creation, but offers limited view of challenges associated with acquiring operations capabilities needed to successfully deliver value proposition and scale up the startup.

Operations management

The academic literature of operations management emphasizes a broad range of issues such as risk and uncertainty (Sommer, Loch, & Dong, 2009; Girotra & Netessine, 2011), supply chain (Mason-Jones & Towill, 1999), capacity planning (Swinney, Cachon, & Netessine, 2011), production and processes (Tanrısever, Erzurumlu, & Joglekar, 2012), technology commercialization (Schmidt & Druehl, 2009), enterprise networks (Buhman, Kekre, & Singhal, 2005), timing of product design and launch (Loch & Terwiesch, 2005), manufacturing operations (Kouvelis, Chambers, & Yu, 2005), and location (Campbell, 1994; Barahona & Jensen, 1998; Kouvelis, Rosenblatt, & Munson, 2004; Bogataj, Grubbström, & Bogataj, 2011).

While closely related to our research question, the bulk of this literature focuses on models that assume a degree of stability and maturity in a firm's marketing and operations functions that may not be realistically descriptive of many startup environments.

To summarize, there is very little written on *operational capabilities* of early stage companies. Available examples illustrate insufficient attention to operations capabilities as a central piece of the entrepreneurial venture and focus on non-core operational problem-solving issues that have limited effect on overall startup performance. Few seem to highlight or capture the path dependency of a startup based on the maturity of its operations model and capabilities. Sobrero & Roberts (2001) focused on *supplier-manufacturer relationships* and found that design scope and task interdependencies affect short-term efficiency and long-term learning opportunities in a trade-off fashion. Roberts (2007) describes comprehensive model of innovation process consisting of recognition of opportunity, idea formulation, problem solving, prototype solution, commercial development, and technology utilization and/or diffusion. The

author explicitly mentions that at the early stages it is a "major mistake is to set up stringent formal processes for approval of the small sums needed to try out an idea" and the question of reliable technical output (proxy for operations capabilities) should come at later stages, such as commercial development. While the feedbacks among stages are acknowledged, there is no discussion of how the timing of formal processes creation might affect success of a startup. Rahmandad (2012) talks about trade-offs of investing in operational capabilities (short-term) vs. dynamic capabilities (long-term), assuming the stage in firm's life where the product has already been created and the challenge is how to capture bigger market share. This topic is very close to our research questions, but we are considering very early startups that are still in the process of figuring out their value proposition and marketing strategies. Tatikonda, Terjesen, Patel, & Parida (2013) specifically explored operational capabilities of entrepreneurial ventures during three life-cycle phases (start-up, growth, and stability) and identified three types of capabilities that need to be acquired (inventory turnover, gross margin, and employee productivity), but didn't explicitly explore conditions affecting intensity and timing of acquiring the operational capabilities.

We next turn to our research questions and explore the factors and key variables that should affect the level, timing and nature of investment in operations capabilities by a startup company.

4. Three stages of organization evolution

As we have seen from the review of the entrepreneurship literature in the previous section, scholars never consider startup companies as time invariant phenomena that are likely to be addressable with steady state models. We find useful a framing of three distinct stages that might be observed in the early to mid-life of any company. In the *earliest* stage, a company works on ideation and creating a value proposition that works simultaneously for all the

members in its proposed value chain (customers, employees, suppliers, distributors, investors, etc.). At his stage, early entrepreneurial intentions, initial resource endowments, rapid product prototyping, and marketing efforts play especially important roles. The *second* stage comes when a company has figured out a viable value proposition and must grow in parallel its market and its production and delivery capabilities. This stage is characterized by extensive focus on processification (establishing reproducibility, delegation, simplicity, and efficiency in processes), professionalization (expanding skill sets and allowing task and process focus), and segmentation (figuring out how the market varies across customers and what product or service variants will be required to serve the identified segments). The *third* stage typically comes much later, after a company realized its value proposition, developed professional processes to deliver it, cultivated substantial customer relations, and gone through its rapid growth phase. At this point, the main focus is sustainability of the business and continuous improvement to navigate the market and avoid organizational rigidity that makes a firm susceptible to disruptive threats.

Borrowing from Furr & Ahlstrom (2011), who explored primarily the first stage, we call these stages, respectively (1) Nail-It (nailing down the value propositions), (2) Scale-It (growing the market and capabilities to serve), and (3) Sail-It (operating in a setting that more resembles a (possibly turbulent) "steady state"). We focus on the evolution of the firm through development of its capabilities, as appropriate for each stage. For many firms, progress through the stages is not unidirectional, as setbacks may lead to "pivoting" and re-thinking an entire value proposition or value chain (Figure 1).

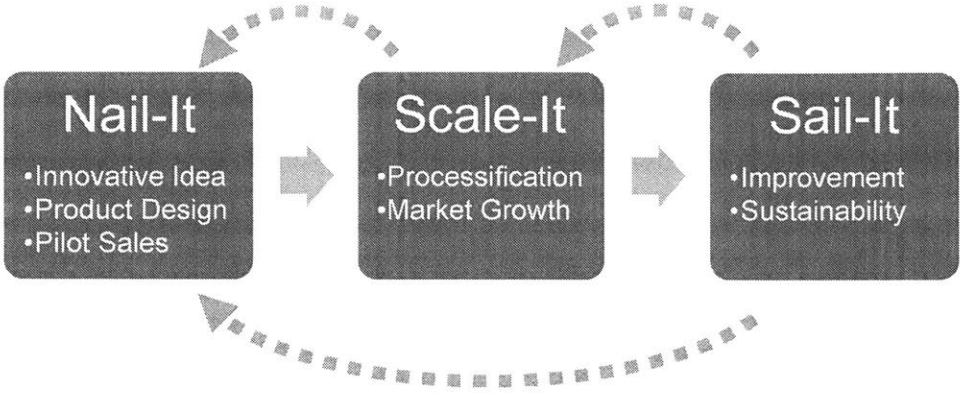

Figure 1. Three stages of entrpereneurial operations

This paper focuses specifically on the timing and nature of the development of operational capabilities in an entrepreneurial venture as it traverses through the Nail-it and Scale-it stages of evolution. We propose that investment in operational capabilities can be planned in three phases within the Nail-it stage – (1) innovative idea, (2) product design, and (3) pilot sales. We seek to explore what effect this choice has on performance of a startup.

The extant literature often conflates operational and dynamic capabilities, sometimes using them interchangeably. Few papers address the issue and provide clear definitions. Cepeda & Vera (2007) suggest that "[o]perational capabilities are geared towards the operational functioning of the firm, including both staff and line activities; these are "how we earn a living now" capabilities." Helfat & Winter (2011) clarify that "an operational capability enables a firm to perform an activity on an on-going basis using more or less the same techniques on the same scale to support existing products and services for the same customer population." In our work, by "operational capabilities" we mean the ability of an organization to produce, package, and deliver, and provide service for its value proposition to end customers.

Our research questions are:

- How can we characterize different strategies for investment timing for operational capabilities?
- What are outcomes affected by using each of these strategies?
- Under what conditions might each of these strategies lead to preferred outcomes?

In what follows, we present our data sample and analyze it to explore the factors and key variables affecting the success of a company through our research lens.

5. Methodology and Data

We have collected extensive data, over a three-year period, through semi-structured interviews, seminars, workshops with entrepreneurs, and personal connections. Our subjects have been companies located in the U.S., China, Israel, Romania, India, Germany, Malaysia, and Singapore, as well as participants attending MBA and executive courses taught at MIT, International Institute for Management Development (IMD) in Switzerland, and the Indian School of Business in 2012-2015.

This extensive fieldwork has resulted in the development of 14 written cases that encapsulate some of our learning to date (**Error! Reference source not found.**). Since our cases were chosen using convenience sampling and some snowballing, we cannot rule out selection bias in our sample. However, the cases are not meant to generalize to the whole population of startups, but rather to provide longitudinal data to illuminate patterns of performance and features of variation in practice that might otherwise be overlooked. Ultimately, perhaps the most important finding from our cases is that the dominant recommended model for an entrepreneur, to find a market and customers first and worry about operations later, may be successfully reversed, and sometimes must be reversed for firm

survival. We found several companies that successfully followed a path of capability development first, markets later. Our research task is to build a theory to help understand when and why this might be a sensible, or even optimal, strategy.

Table 1. Empirical Case Studies

Company	Description	Country
Anwell	Global supplier of advanced manufacturing equipment and process technologies for electronic products	Hong Kong
BGI	Development of science and technology in the field of genome research	China
HubSpot	All-in-one marketing software	USA
MediTech (disguised)	Developer of novel medical devices	India
Metalicone	Manufacturer of top quality, complex technical, high precision metal parts and systems	Israel, Germany
Metropoli/Torero	OEM manufacturer and global licensee for luxury brands, with a specialization in the Leather Accessories category	India, Spain
Ministry of Supply	Professional performance apparel company	USA
Nandi Tyres	OEM tire/tube manufacturer	India
NovaConfort	Construction builder	Romania
NxStage	Manufacturer of home dialysis systems	USA
SkinnyGirl	Low calorie cocktail brand	USA
Tesla	Manufacturer of electric vehicles and battery systems	USA
Unity Homes	Designer/Builder of custom, energy-efficient prefabricated homes and structures	USA
VFA	Business and management education for aspiring entrepreneurs	USA

Cases vignettes

In this subsection we provide a short summary of each case and the lessons learned. Full cases are available from the authors upon request.

Anwell[1]

Anwell was founded in 2000 with its head office in Hong Kong, and built on deep expertise in manufacturing process technology. The company was first established to design and build manufacturing equipment to make optical media discs (e.g., compact discs, CDs, and later DVDs). Over much of the subsequent decade, the company repeatedly pivoted to new products and new markets (e.g., solar panels and OLEDs) using strong manufacturing and R&D as its core capability.

BGI[2]

BGI was founded in Beijing in 1999 (as Beijing Genomics Institute) with the mission of supporting the development of science and technology, building strong research teams, and promoting the development of scientific partnership in genomics field. BGI successfully pursued a strategy to build capabilities first, and then find markets later. The foundation of its value proposition is the excellence in scientific knowledge and related processes (e.g., genomic sequencing), later applied to breeding, healthcare, agriculture and environmental applications.

HubSpot[3]

HubSpot was founded in 2006 with the idea that traditional marketing techniques were less effective in the digital economy when consumers are annoyed with and ignore a vast number of impressions delivered through outbound channels. Instead, HubSpot built its business on the concept of Inbound Marketing, whereby consumers find suppliers through information in social

[1] http://www.anwell.com/eng/index.html
[2] http://bgi-international.com/
[3] http://www.hubspot.com/

media, blogs, etc. rather than through mass-mailing campaigns. After proving the effectiveness of Inbound Marketing with pilot customers, HubSpot developed all-in-one software platform, which required multiple iterations and major re-designs along the way. Formal processes and organizational capabilities entered the scope of firm's strategy with the growth of its customer base. HubSpot has helped more than 11,000 customers in 70 countries attract leads and convert them into customers.

MediTech

A disguised, composite company in India developed a novel medical device to improve brain imaging during cranial surgery by heightening image resolution through exploitation of technological advances in imaging, and adding in algorithmic innovation and computational horsepower to interpret the images. Presenting their improved images with an appealing user interface, MediTech's solution had the potential to markedly increase cranial surgery outcomes. However, the supply chain operations did not figure strongly into the design developed by the engineering team. Having selected large and famous suppliers in the relevant fields at the request of its engineering team, MediTech lacked bargaining power with these suppliers, and the prototype development and manufacturing cycles were consequently elongated. The company didn't have enough cash to endure these delays and couldn't fund sufficient prototype iterations to secure FDA approval. Being unable to secure more funding from investors, the company was eventually acquired by a competitor.

Metalicone[4]

Metalicone was launched to provide top quality, technically complex, high precision, machined metal parts and systems that use such parts. Early activities focused on achieving and perfecting the manufacturing processes while postponing development of markets or

[4] http://metalicone.com/

customers. With strong emphasis on its capabilities, Metalicone's state-of-the-art technologies and know-how grew to serve leading companies in various industries. The end markets included machine tool, heavy-duty machines, commercial printing, aerospace, semiconductors and manufacturing equipment.

Metropoli/Torero[5]

Based in Calcutta, Metropoli is a family owned business with a long history of manufacturing and exporting leather wallets, handbags, and other accessories as a contract manufacturer for fashion brands. Its early reliance on channel partners for design concepts and market intelligence enabled management to focus on operational excellence and high quality. Once its operational expertise was established, the company was able to successfully expand into design and manufacturing of its own (licensed) branded items.

Ministry of Supply[6]

Ministry of Supply was founded in 2010 at MIT by a team of engineers, designers, and material scientists, with the mission to invent a line of men's business apparel that was classy, yet comfortable and durable in the face extreme usage conditions. The team combined clever marketing with advanced materials and innovative product design in a business model aimed at young business professionals. Early focus on concept marketing allowed the company to attract a lot of attention and generate early sales. However, the company was not well prepared for the operational challenges of producing and delivering products to their retail store customers. Confronted with growing demand and the necessity to deliver large batches of apparel items through traditional and online channels, the company realized late the need to focus on operational capabilities in order to grow its business.

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[5] http://www.metropolifashions.com/
[6] http://ministryofsupply.com/

Nandi Tyres[7]

Operating out of two plants located in Hyderabad, India, Nandi Tyres founded in 1990 is a tire and tube manufacturing company. After many years of running a low efficiency, labor intensive operation to aftermarket tire tubes for agricultural tractors and 2-wheelers, the company decided to start manufacturing tires and works towards serving the OEM market. Toward this end, the company opened a new, more capital-intensive plant to work towards full compliance with product quality requirements demanded by OEMs. The company pivoted to concurrent focus on both product design and manufacturing processes, as well as after sales service to fulfill its expanded aspirations.

NovaConfort

A small family-owned construction company in Romania grew rapidly and profitably under the guidance of its husband-and-wife owner/manager team. The company was able to successfully bootstrap its capabilities through rapid organizational learning. Yet, some of the key learnings have not passed beyond the founders, who are now facing the challenge of growing operational capability in the absence of formal processes and a broader leadership team.

NxStage[8]

NxStage developed System One, a portable home Hemodialysis device that gives kidney dialysis patients the ability to receive the critical renal care at home, avoiding frequent and time consuming trips to the hospitals, and improving overall health due to the ability to add more dialysis treatments per week. The technology provided a breakthrough for patient experience at

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[7] http://nandityres.com/
[8] http://www.nxstage.com/

a very attractive cost, and the company developed an operational capability to provide the dialysis equipment as well as an ongoing supply of consumables to patients across their geographic markets. However, the company struggled to achieve a breakthrough in its business results as many nephrologists did not have incentives to switch their patients from traditional dialysis centers to home treatment.

SkinnyGirl[9]

SkinnyGirl Cocktails started from the mind of entrepreneur and reality TV star Bethenny Frankel as a response to unmet female customer needs to enjoy a drink without the extra calories. Frankel's television presence quickly turned SkinnyGirl into a cocktail revolution and became the fastest growing brand of spirits in the US in 2011. Phenomenally successful in the marketplace, SkinnyGirl struggled to develop operational and supply chain capabilities in time to keep up with market demands and the cocktail business was sold to a large beverage company for a value seemingly significantly below the net present value of its future cash flows.

Tesla Motors[10]

In the case of Tesla's first car, the Roadster, Tesla's designed an initial supply chain that spanned three continents and resulted in very long prototyping cycles. The outsourcing model was not sustainable and the company had to reorganize and redesign its operations toward more insourced manufacturing before it was able to deliver its final products. The initial thought that keeping costs under control by outsourcing manufacturing to low cost geographies was supplanted by the insight that supply chain speed can often save more money than low cost labor. An extreme operations pivot under duress, as experienced by Tesla, is often not possible for a company that doesn't have backers with deep pockets.

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[9] http://skinnygirlcocktails.com/
[10] http://www.teslamotors.com/

Unity Homes[11]

Through its fabrication of highly insulated and finished panelized subassemblies, and its proprietary design platform that makes a home flexible and adaptable to its owners' needs over time, the Bensonwood Homes became a premier designer/builder of energy efficient, high performance, luxury homes across the US and Canada. Bensonwood's subsidiary, Unity Homes, was founded to penetrate the mass market of medium size and price homes. Building on well perfected operational and manufacturing capabilities for the low-volume, premium segment, the company needed to develop the right combination of flexibility, product standardization, and marketing to attract both end customers and builders. This means creating a new system while leveraging operational capabilities from the existing business model of Unity's parent.

VFA[12]

Venture for America (VFA) offers a business and management internship "fellows" program that matches high-capability U.S. millennials with startup companies that might not otherwise have ready access to high-capability talent. VFA targets small, entrepreneurial ventures in second tier entrepreneurial U.S. cities (i.e., outside places like Silicon Valley, Boston, Austin, Seattle, and New York City). The company balanced well the evolution of its multi-sided platform needed to attract fellows, entrepreneurs with startups companies, and program funding providers as they scaled up their volume of matches and the number of cities they penetrated.

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[11] http://unityhomes.com/

[12] http://ventureforamerica.org/

Mapping framework

Each of our case studies has been mapped in Table 2 according to its investment in operations capabilities in each phase, along with its core value proposition (in bold), and a coarse assessment of the state of performance of the associated venture as of 2015: growth or successful exit, rise then fall or stagnation, and sale or refinance/pivot under duress. Each of these options reflects the underlying performance of a company at the time of evaluation. As a measure of performance we used a composite index combining available data that (1) measure growth: perceived growth in cash flow and sales, and (2) measure business volume: sales, earnings, and net worth (Chandler & Hanks, 1994).

Table 2. Mapping of empirical cases

	Investment in Ops during:		
	Innovative Idea	Product Design	Pilot Sales
Growth or successful exit	Anwell **process** Metropoli/Torero **process** BGI **know-how** Metalicone **process**	Nandi Tyres **product/process** Unity Homes **product/process** VFA **business/educational platform**	Ministry of Supply **innovative consumer product** HubSpot **SaaS**
Rise then fall or stagnation	NxStage **safety critical innovative product**	Novaconfort **process**	SkinnyGirl **brand**
Sale or Refinance/pivot under duress			Tesla (Roadster) **safety critical innovative product** MediTech **safety critical innovative product**

From this table, a few observations can be drawn. First of all, almost all companies that focused on a product rather than process invested in ops later (Tesla, MediTech, Skinny Girl, Nandi Tyres, Unity Homes, VFA, Ministry of Supply, and HubSpot). Among those, the success rate is strongly contingent on the actual value proposition. For true product companies (Nandi Tyres, Unity Homes, VFA, Ministry of Supply, and HubSpot), this strategy was reasonable and resulted in successful outcome. For others, where the core value was in underlying process (Tesla, MediTech, Novaconfort, and SkinnyGirl), postponing investment in ops hindered performance and led to failure or stagnation. In addition, premature investment in ops to deliver the value without securing the market was also suboptimal (NxStage). Only pure process companies (Anwell, Metropoli/Torero, BGI, and Metalicone) benefited from early building of ops capabilities. These observations suggest a common pattern where the value proposition defines the timing of investment in ops needed to succeed.

Dynamic Hypotheses

Based on the data from our case studies, we hypothesize that *process centrality* of the value proposition influences the appropriate timing of investment in operations capabilities. Our principal conjecture is that businesses and business models vary by the degree to which they are product-centric, process-centric or "balanced." Specifically, we presume a category of value proposition that is *process centric*, where the specific product can be defined later. In our casework, BGI, a company that sells genomic sequencing services, focused early on perfecting its ability to execute the processes of genomic sequencing, without knowing what products or services the company might eventually sell. In such cases, early investment focuses on know-how or patented IP for processes, rather than products. A second category of value proposition focuses on *innovative products that also require distinctive and capable operations*. Also in this category are businesses that aim to manufacture a product for which quality cannot be compromised and use of minimum viable product with low quality and missing features is not

acceptable (safety critical products). In our casework, Unity Homes, a maker of pre-fabricated, premium homes, found that they had to simultaneously innovate their product and process designs to fulfill the promise of their business model. The third category considers value propositions where the lion's share of the value comes from the *product*, and process capability plays a definitively secondary role. In our case studies, the enterprise value of HubSpot was almost all in the product development, and minimally in the operations capabilities.

Specifically, we hypothesize:

(1) If the core value proposition of a firm is a *process, when specific product can be defined later*, then early investment in operations (during *Innovative Idea* phase) maximizes the value of the firm.

(2) If the core value proposition of a firm is an innovative *product created and delivered through excellent and/or innovative operations*, then investment in operations concurrent with product design and development (during *Product Design* phase) will maximize value.

(3) If the core value proposition of a firm is an innovative *product that can be created and delivered with an ad hoc set of processes,* then investment in operations much later (during *Pilot Sales* phase) does not jeopardize the value proposition.

At their face, these propositions may appear to be almost tautological. However, we believe that the definitions and characterizations we have deployed highlight precisely an important set of distinctions that have heretofore not been adequately explored. In particular, our evolving modeling work suggests how early-stage firms need to shape their investment strategies in response to the distinctions we highlight.

6. Causal loop diagram and Systems Dynamics model

In this chapter we build the causal structure of the model using the System Dynamics causal loop diagram that captures core interactions between main variables. We then use this diagram to build a fully specified dynamic model that can be used to explore the behavior of the system.

In order to capture the complex dynamics of a startup environment, we use System Dynamics tools to build a causal loop diagram and then a full simulation model. To represent the core processes typical for an organization's early stage, when the value proposition is not yet well defined, we have chosen a small subset of variables to capture dynamics and provide clarity. The resulting diagram is presented in Figure 2[13], where all the processes of the value proposition -- ideation, design, manufacturing, and delivery -- are represented by feedback links. Specifically, we consider four key variables:

(1) *Product Design* is the state of the maturity and quality offered by the firm's product. This variable is modeled as the cumulative effort and experience invested in improving design features of the value proposition, measured in dollars,

(2) *Operational Capabilities* represent cumulative effort and experience invested in developing operational capabilities to produce and deliver the value proposition, measured in dollars,

(3) *Production Quantity* represents the output of a company activity, measured in units/month, and

[13] Arrows indicate causality, plus and minus indicate the relationship: a "+" means that, *ceteris paribus,* an increase (decrease) in the independent variable causes increase (decrease) in the dependent variable compared to what it would have been, had the independent variable not changed, a "-" reverses this definition: *ceteris paribus,* an increase (decrease) in the independent variable causes decrease (increase) in the dependent variable compared to what it would have been, had the independent variable not changed (Sterman, 2000).

(4) *Revenue* represents the money resulting from the sale of production, measured in dollars/month.

The model also captures three additional variables related to the value proposition:

(1) *Product Design Obsolescence* represents the decay in the value of design features for consumers due to ongoing innovation and market evolution, measured in dollars/month,

(2) *Operational Capabilities Erosion* represents the ongoing depreciation or loss of relevance of tools, equipment, training and/or relationships, measured in dollars/month, and

(3) *Share of Product Design in Value Proposition* captures the above-mentioned relative value of product features vs. process capability in the firm's value proposition, dimensionless.

The dynamics of the system work as follows. The firm's investment in *Product Design* defines *Product Quality*, and investment in *Operational Capabilities* defines *Process Quality* and *Production Quantity*. Combined, *Product Quality* and *Process Quality* generate the *Value Proposition*, which influences the *Price* that customers are willing to pay. *Price* and *Production Quantity* define *Revenue*. After collecting *Revenue* each period, the company makes a resource allocation decision: what fraction of revenue to reinvest in improving the value proposition, which is distributed among *Cash to Increase Product Design* and *Cash to Increase Operational Capabilities* according to the *Operations Investment Timing*. Of course, since few startup companies are capable of generating revenue in the earliest stages of existence, we assume

that the firm relies on external financing, represented by *Initial Investment*. The full cycle forms three reinforcing loops[14] (R1, R2, and R3) that capture the driving force of company success.

Reflecting that no real quantity can grow forever, the model includes two balancing loops (B1 and B2) that constrain the growth of the company as the result of ongoing diminution in *Product Design* and *Operational Capabilities* due to competition and/or technological obsolescence. In addition, the balancing loop B3 is formed through a feedback link from *Product Design Obsolescence* to *Operational Capabilities Erosion*. This link represents the phenomenon that as *Product Design* features become obsolete (short half-life time), they can drag along and reduce *Operational Capabilities* (long half-life cycle) that are idiosyncratic to them, thus undermining the whole chain of the firm's processes and capital stocks and reducing the overall value proposition even faster.

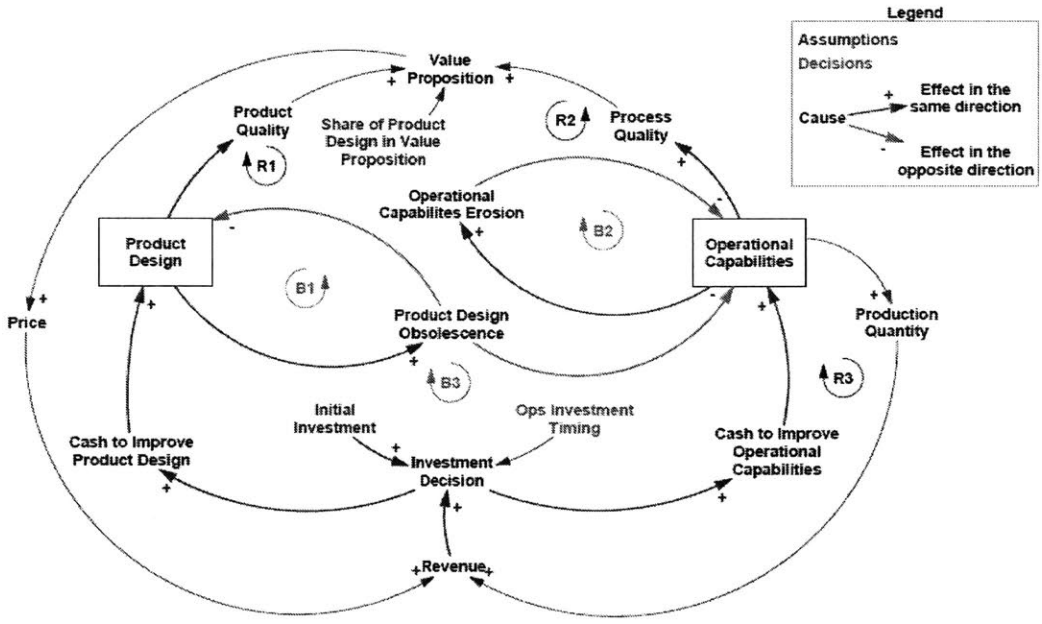

Figure 2. Causal Loop Diagram of Value Proposition creation and delivery

[14] A reinforcing loop is a loop with positive open loop gain, i.e. it amplifies the change in any of the variables after full cycle, while balancing loop is a loop with negative open loop gain, i.e. it reduces the initial change in any of the variables after full cycle (see Sterman (2000) for an excellent discussion).

The behavior of the system is generated through interaction between the main feedback loops: (1) the two reinforcing loops (R1 and R2) related to quality of value proposition: revenue generation through investment in product design and revenue generation through investment in operational capabilities, and one reinforcing loop (R3) of production quantity through investment in operational capabilities, and (2) the three balancing loops (B1, B2, and B3) that respectively represent the ongoing decay of product design capabilities, the decay of operational capabilities, and the aforementioned additional reduction of operational capabilities that occurs when product design features serviced by operational capabilities become obsolete.

The complexity of these interactions prohibit the ad-hoc analysis, so, we have developed a fully specified Systems Dynamics (SD) model (Figure 3) that explains outcomes in empirical cases as a function of timing and intensity of investment in operational capabilities. The model was developed in Vensim and full documentation is available in Appendix A. Model Documentation. The model has two stock variables (product design and operational capabilities) and uses Euler integration to numerically solve system of nonlinear differential equations.

The model has the following assumptions:

- A single firm is in the marketplace (competitors are not modeled explicitly, but the effects of competition, arising from a constantly eroding product competitive advantage, are explicit in the model).
- The firm sets a price, based partly on costs, that enables it to exactly sell out its capacity.
- The value proposition is a function of two inputs – product quality and process quality.
- Production is a concave function of operational capabilities.
- Decision making is open loop -- the strategy is fixed at the beginning of simulation.

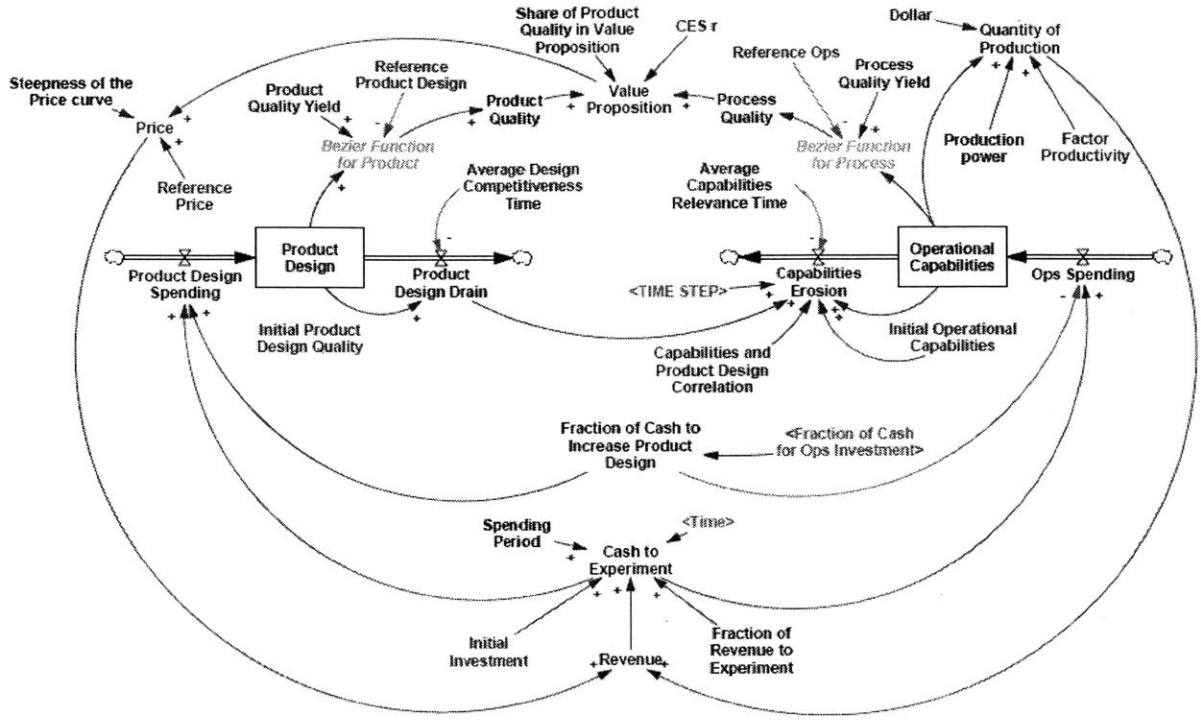

Figure 3. System Dynamics Model

The value proposition of company is modeled as the CES (constant elasticity of substitution) function of two inputs – product quality and process quality – which allows us to analyze model behavior under different assumptions about relations between product and process quality, from perfect substitutes to Cobb-Douglas to perfect complements. The equation for the value proposition is:

$$V = \left(s_q Q_{product}^r + (1 - s_q) Q_{process}^r\right)^{\frac{1}{r}}$$

where s_q is share of product quality in the value proposition, $Q_{product}$ is product quality, $Q_{process}$ is process quality, and r is the CES coefficient that affects function behavior as follows: if $r = 1$, inputs are perfect substitutes, if $r = 0$, function is Cobb-Douglas, where doubling any of the inputs doubles the output, if $r = -\infty$, inputs are perfect complements.

The relation of price to value proposition, varies from 0 (no value proposition) to 1 (full value proposition) relative to the desired market value, and is strictly convex with price rising very slowly when the value proposition is low and rapidly increasing as the value proposition approaches 1. This behavior assumes that consumers are willing to pay a fraction of the full price if the product is not yet perfect. Specifically, a convex shape ensures that firms need to deliver significantly on their promises before they can charge a meaningful price. The equation for price is:

$$P = e^{-\alpha*(1-V)} * P_r$$

where α is steepness of the price curve and P_r is reference price at full value proposition $V = 1$.

The relationship between product design and product quality and between operational capabilities and process quality are generally complex and depend on the specifics of business model and environment. For the model, we chose to use cubic Bezier curves to describe how process and product quality depends on respective investment in product design and operations capabilities.

$$B(t) = (1-t)^3 * P_0 + 3(1-t)^2 * t * P_1 + 3(1-t) * t^2 * P_2 + t^3 * P_3, \qquad 0 \leq t \leq 1$$

where $P_i, i = 0, \ldots, 3$ are control points.

Cubic Bezier curves can easily be independently shaped as convex, S-shaped, and concave (Figure 4), thus covering the whole landscape of potential combinations. Indeed, convex shape assumes that the slope of quality is increasing, which means that investments do not generate substantial quality in the beginning, but after a certain investment threshold (typically about 70%) the quality increases rapidly. S-shaped curve assumes slow uptake of quality in the beginning, fastest increase around midpoint, and leveling off after about 70% with almost full saturation around 90% of investment. Concave shape has decreasing slope, which

means there is a substantial increase in quality in the beginning of investment, but after the investment reaches about 30%, the quality begins leveling off and almost fully saturates at about 90% of investment. In addition to the shape, we also checked whether the steepness of the curves matters and found that it affects the magnitude of the results, but not the qualitative behavior.

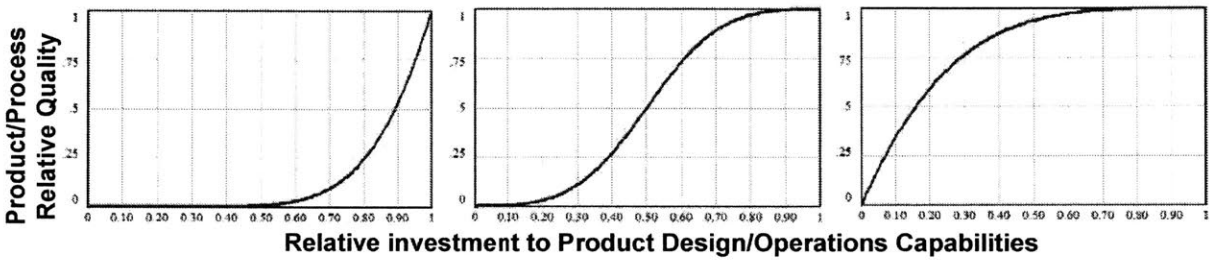

Figure 4. Potential shape of nonlinear product/process quality functions

7. Results

In this chapter, we use the model to validate our hypotheses and explore the optimal strategies. First, we assume a simple two-period investment strategy when the decision to invest in operational capabilities is made once the product design is considered complete, and the allocation cannot be split (all resources are invested in either product design or operational capabilities). We use the model to explore the relations between timing of investment in operational capabilities and success under different compositions of value propositions and environmental conditions. Second, we relax the assumption of the simple strategy and allow the investment to be switched multiple times and also smoothly allocated between product design and operations capabilities. We identify the optimal strategy for investment in operations capabilities and compare the results with the simple investment strategy. We find that for any mixed value propositions (not purely process or product centric) a flexible investment strategy

with three periods outperforms the simple two-period strategy and suggest practical application of the optimal strategy for managers facing uncertainty in estimating the model parameters.

Because we are modeling startup companies, the variation of the values of the constants in the model could be enormous. A wide variety of business models, strategies, value propositions, investor relationships, consumer perceptions, and marketing efforts makes it impossible to talk about an "average" startup. However, we do not intend to make predictions about any specific startup, but rather elicit from the model qualitative insights into modes of behavior and how they relate to the investment strategies. Therefore, we have chosen quite arbitrary values to initialize the model and we have also performed sensitivity analysis to verify the robustness of the conclusions.

So, for concreteness, we assume that the initial seed money available from investors is $350,000 for a period of 30 months, after which the firm is assumed to be self-sustaining. Full sales price of the product at complete value proposition is $500, and the reference product design and operations capabilities investments to reach full quality of product and process are $100,000 each. We also assume that product design relevance time is 12 months, while for operations capabilities this constant is 120 months, reflecting more durable nature of operational capabilities (machinery, manufacturing knowledge) compared to product design features that are subject to rapid change due to technological progress and the effects of competition. Correlation between product design and operations capabilities is assumed to be 0.5, which means that for every dollar of Product Design investments lost due to obsolescence, half of the same amount is drained from Operations Capabilities stock. Full list of initial assumptions of the model is presented in Table 3. The model runs for 120 months to allow enough time for all feedbacks to manifest and show specific pattern of behavior.

Table 3. Initial Assumptions of the Model

Variable	Initial Value
Initial Investment Initial funding available from investors	$350,000
Spending Period Period of financing, it is assumed that initial funding is equally spread over this time	30 months
Reference Price Full sales price of the product if the full value proposition is achieved	$500
Initial Product Design Quality Initial product design features as represented by innovative idea	$100
Reference Product Design Value of investment in product design at which full product quality is achieved	$100,000
Product Quality Yield Yield of investment in product design	1
Initial Operational Capabilities Initial operational capabilities as represented by "garage facilities" of founders	$100
Reference Ops Value of investment in operational capabilities at which full process quality is achieved	$100,000
Process Quality Yield Yield of investment in operational capabilities	1
Capabilities and Product Design Correlation Correlation between product design and operations capabilities	0.5
Average Design Competitiveness Time Average time a product design investment remains competitive	12 months
Average Capabilities Relevance Time Average time an operational capabilities investment remains competitive	120 months

Product Design Improvement Fractional Rate Fractional investment in product design after switching to investment in operations capabilities	0.01
Steepness of the Price curve Responsiveness of sales price to value proposition	10
CES r Coefficient of CES value proposition function	-1
Factor Productivity Productivity of 1 unit of operational capability	5 widgets/month
Production power Exponent of production function adjusting the responsiveness of the output as a function of ops capabilities	0.5

Our principal hypothesis is that timing of investment in operations capabilities should be a function of the degree to which the value proposition is product-centric, process-centric or "balanced." Further, our case studies suggest that entrepreneurs can make errors in their business choices, e.g., choosing to defer investment in operations capabilities when the business actually requires early investment in such capabilities. In addition, we also don't know the exact relation of product and process quality to the investment in product design and operations capabilities respectively. Thus we proceed as follows. We explore the full landscape of potential combinations of quality functions (there are 3 options for each product and process, which gives nine possible combinations) that reflects the uncertainty about the environment -- and for each we explore full spectrum of value proposition composition – from full process-centric to fully product-centric – and full range of investment strategies – from investing in operations from the very beginning to never investing in operations.

The model assumes that process investment begins once the decision is made to "freeze" the product design. That is, once the product design is complete (they "nailed" it), then the firm invests the maximum possible amount of money in operations ("Scale-It phase"), leaving just

enough investment in product design to compensate for ongoing product obsolescence and a small fraction in product improvement (as defined by Product Design Improvement Fractional Rate). The model only considers one generation of product.

We ran the nine possible scenarios to see whether the model would generate the behaviors we expected. Figure 5 shows our results. As we travel across panels, we improve product quality responsiveness (convex to S-shaped to concave), while traveling down improves process quality responsiveness, i.e. panel 5 corresponds to the environment where both product and process quality as a function of investment follow S-shaped curve. In every such environment, we vary process centrality (X axis) by changing share of product quality in value proposition vs. investment strategy (Y axis) by changing the timing of investment in operational capabilities. Resulting plot shows financial performance of a company (10-year CAGR) where lighter colors represent lower performance (white color is effectively bankruptcy where CAGR is 0%) and darker shades of blue indicate increasing performance. Two-way ANOVA shows statistically significant effect of both product (columns, $F = 25976.07, df = 2, p = 0$) and process (rows, $F = 5026.36, df = 2, p = 0$) quality responsiveness, as well as their interaction ($F = 899.52, df = 4, p = 0$).

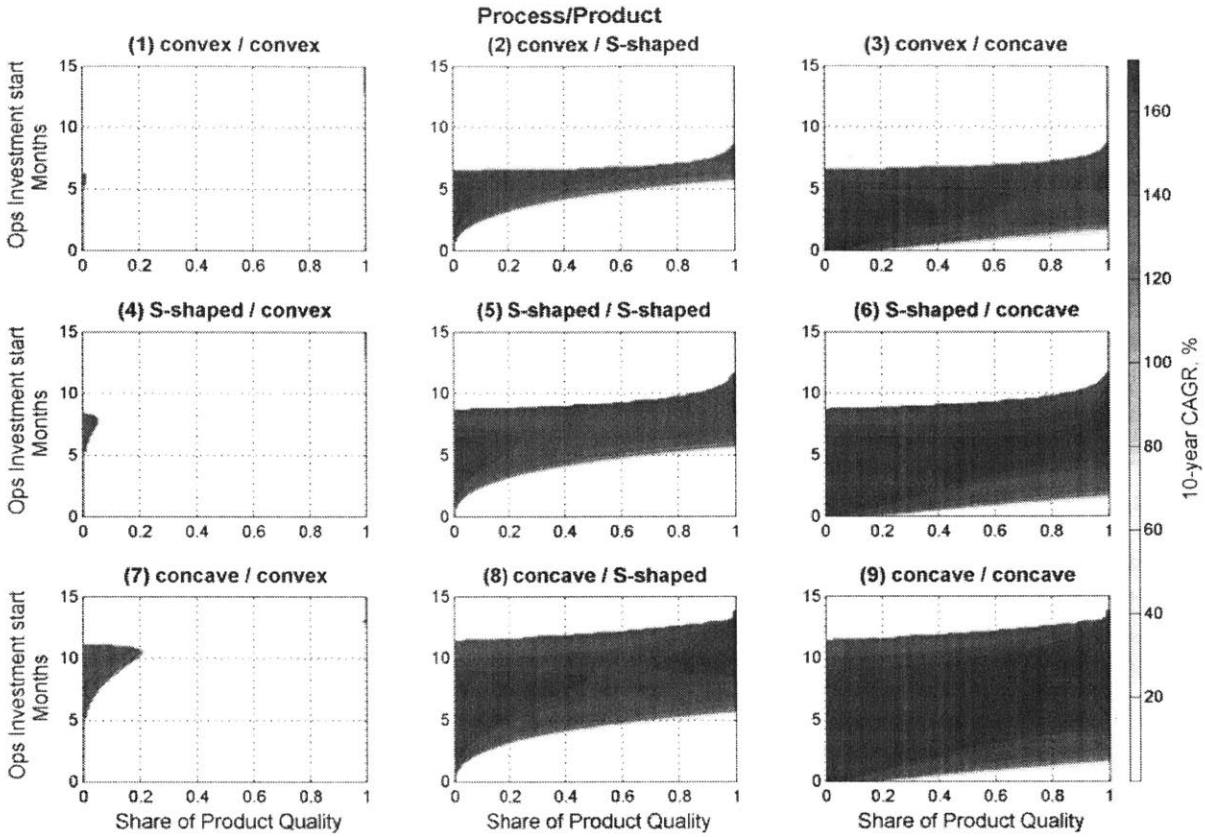

Figure 5. Financial performance (10-year CAGR)

We find support for our hypothesis, specifically in all panels we observe that as the share of product quality in value proposition increases, the optimal timing of investment in operations capabilities pushes back more. Consistent with our hypothesis, this means that for value propositions that are more process centric, earlier investment in operations capabilities results in better financial performance, while for value proposition that relies on specific product features, investment in operations capabilities needs to be delayed until product quality is improved through early experimentation with minimum viable product.

When no investment in operations capabilities is scheduled, the firm's revenue is insufficient by the time the Initial Investment period is over due to lack of manufacturing capabilities. In this scenario the firm fails immediately after the seed money runs out. With small amounts of

investment in operations capability, the company still fails, despite the fact that some operational capabilities were built. In this case, too much focus on design and too little capacity doesn't generate sufficient revenue to overtake the balancing reduction loops (B1 and B2) that drain operations and design value. In order to be successful, the company needs to invest in operations early and sufficiently, so that a sufficient value proposition can be delivered through operations, thus generating virtuous momentum in reinforcing loops (R1, R2, and R3), which overcome the balancing reduction loops (B1 and B2).

Too early investment in operations capabilities when the product design features are not sufficient generates initial success as the lower drain of ops capabilities allows the virtuous momentum in reinforcing loops R1 and R2 to dominate in the beginning. However, the revenue generated from early sales is not enough due to low sales price reflecting incomplete value proposition, and eventually the positive momentum is overtaken by the design reduction feedback loop (B3). The model shows that early investment in operations capabilities are justified for process centric companies when value proposition is mostly defined by ops capabilities. For mixed or purely design centric value proposition early investment in ops results in failure to create a product with value proposition aligned with customers/partners since early Ops might impede experimentation and pivoting.

As suggested by the variation in our case studies and reinforced by the model simulation, there is substantial leeway for managers as to exactly when to invest in operations – and still experience success. However, the width of the safe decision time band when switching to ops leads to success depends on the environmental factors that define the shape of quality curves for product and process, as can be seen in Figure 5. For the most challenging environment, where both quality curves are convex, i.e., there is a long delay before the investments result in a quality that can generate revenue, positive profit is difficult to achieve regardless of the investment strategy (Panel 1). As we travel to more forgiving environments (Panels 2 to 8), the

band of profitable timing options widens, allowing for more variation in outcomes and less sensitivity to investment timing errors. Panel 9 represents the most welcoming environment, with both curves being concave, which means that initial investments very quickly result in sufficient quality and the company becomes profitable very soon.

We note that effect of the shape of the quality functions is not symmetric. Going from Panel 1 to Panel 3 (improving responsiveness of product quality) makes a huge difference, whereby there is a full suite of possibilities for a firm to succeed with any value proposition in Panel 3. However, as we go from Panel 1 to Panel 7 (improving responsiveness of process quality), the situation improves only slightly, with successful value propositions still being around most extreme cases of product-centric or process-centric. The phenomenon is due to the lower average time a product design remains competitive (12 months) compared to operations capabilities (120 months). This means that *ceteris paribus* more investment is needed in product design then in operations capabilities to achieve the same level of quality. Low responsiveness of product quality means that Nail-It phase needs to take much longer before product quality increases to a reasonable level enough to generate sustainable revenue, and if the manager switches from Nail-It to Scale-It phase too quickly, the product would not be mature enough to sell. However, the option to prototype longer may not be available as the initial investment is not sufficient to cover it. This confirms the common intuition that a company needs to carefully plan and raise the investment needed to both nail its value proposition and begin scaling operations in time. If anything, balanced value propositions where product and process quality both matter significantly, are most vulnerable to the amount of cash a startup has, especially under conditions where the product is very novel and requires a lot of prototype cycles.

The results of the model are sensitive to the initial assumptions quantitatively and also qualitatively. In general, abundance of funds allows a company to excel in any environment and shape of quality functions. Therefore, varying initial investment, spending period, and product

price results in trivial increase in probability of making positive revenue. However, the more interesting question is the effect of change in curvature of quality functions, since this is the most uncertain parameter that is extremely hard to estimate. We found that while curvature changes specific time of optimal investment, the qualitative results related to the shape of the quality function (convex, S-shaped, and concave) hold in line with the discussion above. Another factor that affects qualitative behavior of the model is Capabilities and Product Design Correlation. Obviously, this variable creates the important feedback loop B3 that we discussed above, therefore higher values should lead to lower performance similar to tough environments with concave quality functions. We performed the sensitivity analysis varying this correlation from 0.1 to 0.9. Example of sensitivity runs for Panel 5 from Figure 5 is shown in Figure 6. Here, the middle panel is exactly identical to the Panel 5 from Figure 5 (correlation is equal to the initial value of 0.5) and the other panels show performance for different values of correlation.

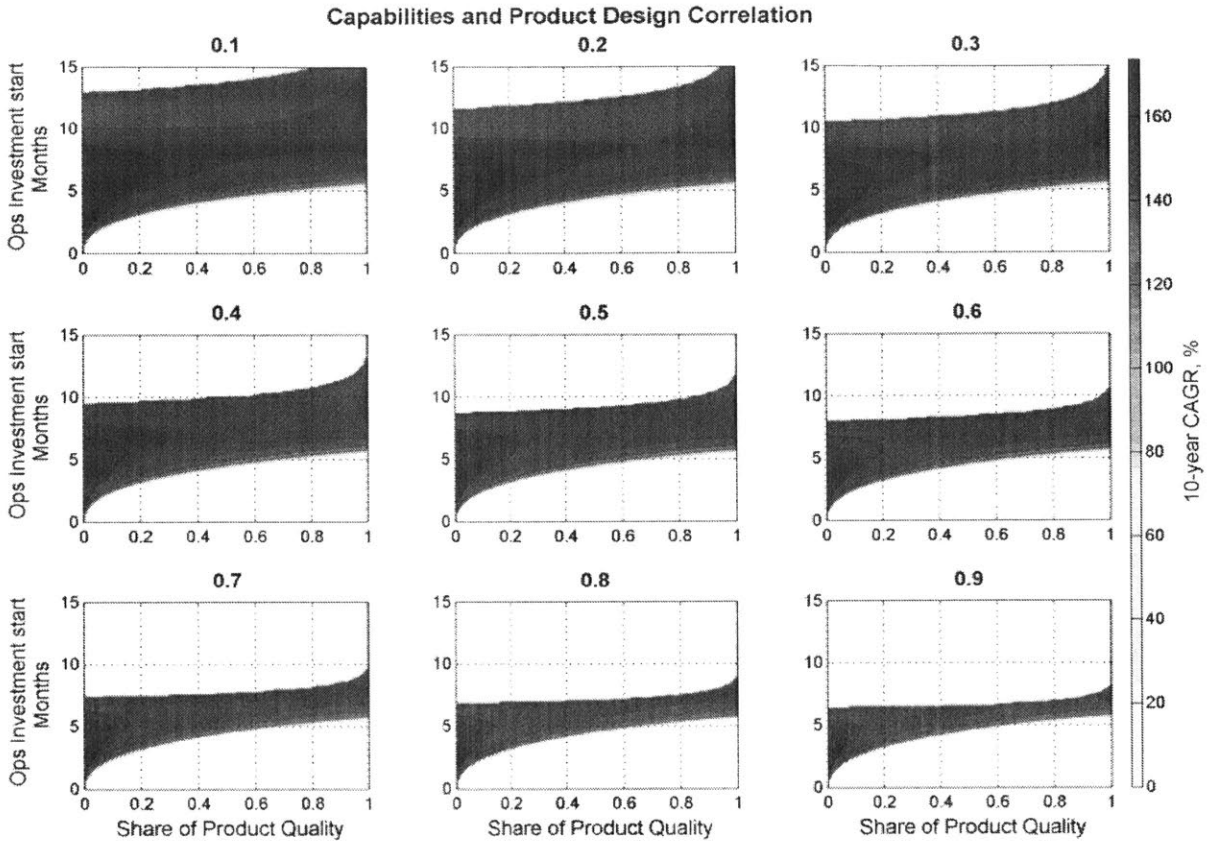

Figure 6. Sensitivity analysis of Capabilities and Product Design Correlation

One-way ANOVA shows statistically significant effect of Capabilities and Product Design Correlation on performance ($F = 2142.38, df = 8, p = 0$). Results for other panels are qualitatively similar. The analysis clearly demonstrates the importance of considering feedback loop B3 and illustrates the effect of its strength (higher values of correlation means stronger balancing loops constraining performance). For the very high correlation (which means extremely customized operations capabilities that are highly correlated with product design, hence they become obsolete as soon as the product design is replaced), a firm must constantly acquire new operational capabilities every time product design changes, which leads to an insufficient revenue from sales while the new capabilities are being accumulated. For the very low correlation (which means operations capabilities are standard and can be used for any

product design features), a firm can save on investment in new operations capabilities and continue to deliver its product or service even as the design changes.

We next use the model to find the optimal strategy for investment in operations capabilities if managers could smoothly and continuously alter the fraction of investment. The optimization is done using 30th order Chebyshev polynomials of the first kind:

$$T_n(x) = \cos\big((n-1) * \arccos(x)\big), \qquad n = 1 \ldots 30$$

These polynomials are orthogonal, so there is no correlation between them and approximation is more accurate. The optimal fraction of cash for ops investment at each time step is then

$$\delta_i = \sum_{n=1}^{30} \beta_n T_n(\tau_i)$$

Where β_n is polynomial coefficient and τ_i is fraction of time between start and end of simulation at each time step. Since τ_i is varying between 0 (simulation start) and 1 (simulation end), we can use trigonometric definition of Chebyshev polynomials and the optimization just needs to determine polynomial coefficients β_n.

Figure 7 shows one such optimization for the environment with S-shaped quality functions for both product and process (Panel 5 in Figure 5). The optimal path for any value proposition is a vertical line from time 0 where color intensity along the line indicates the optimal fraction of cash to invest in ops at any point in time (example for value proposition equal to 0.89 is shown by dashed red line).

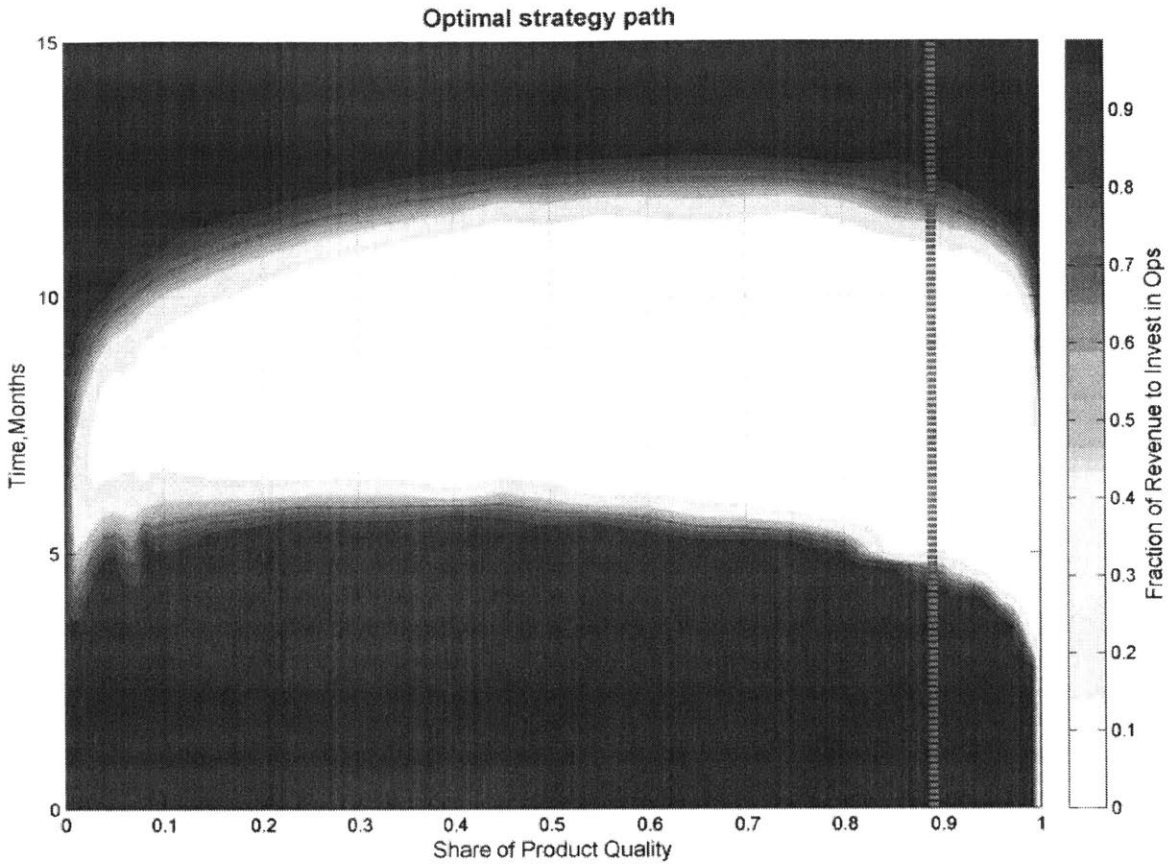

Figure 7. Optimal strategy for different value propositions

The comparison between simple nail-it scale-it strategy and optimized strategy for Panel 5 from Figure 5 is shown in Figure 8. The gain is clearly visible for mixed value propositions, where both product and process are important (with more gain for product-centric value propositions), while the pure process or product value propositions don't show any improvement. No gain from optimization at the limits means that simple strategy provides the best solution. Indeed, for 100% process centric value proposition a firm must invest in ops from the very beginning (product design doesn't matter at all), while for 100% product centric value proposition a firm must invest in product until it matures (process doesn't add any value) and then switch to ops just to deliver the product (operations capabilities in this case only matter for manufacturing, but not for the creation of value proposition). For a mixed value proposition, the

optimization suggests a strategy where a firm first pre-invests in ops, then switches to product design until it matures (duration of this phase depends on the share of product design in value proposition), and finally invests in ops when its ready to scale up. Such strategy provides a spring board for a firm by having operational capabilities ready for scaling up immediately after the product design is mature enough, leading to higher financial performance.

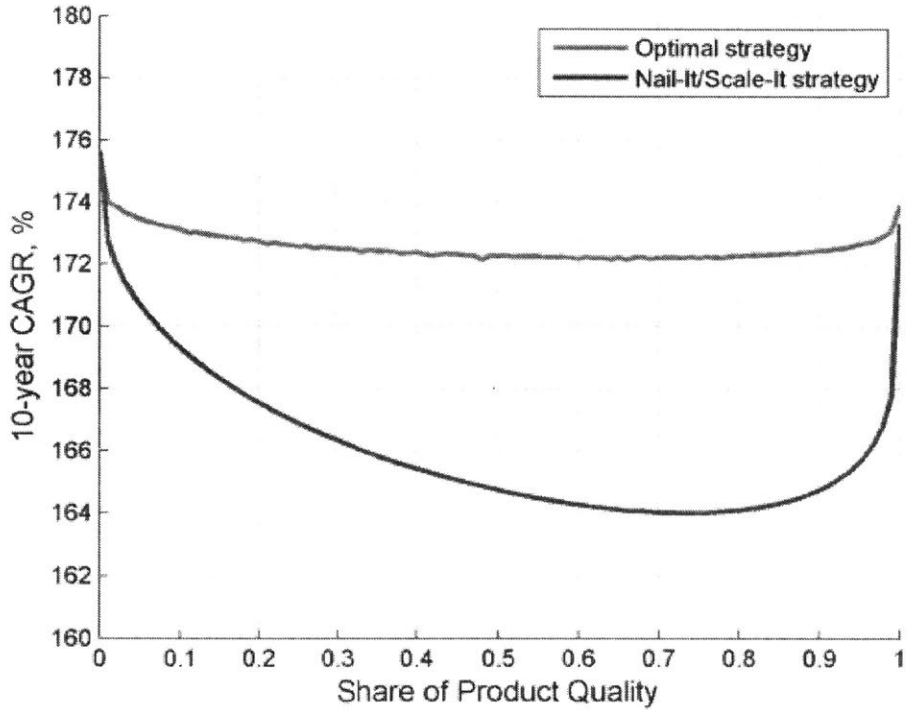

Figure 8. Comparison of simple vs. optimal strategy

The optimization confirms our main hypothesis that the more product centric value proposition is the later the company should stop investing in product design and switch to investment in ops. Also, the required duration of investment in product design increases as we move to higher share of product in value proposition (see the width of the wide band in Figure 7 increasing as we move to the right), which reflects the fact that the such value propositions require stronger product design, i.e. more investment to achieve it.

The main insight from the optimization is that in the beginning there should be no investment in product design for any value proposition until some operations capabilities are built. Such conclusion, of course, is counterintuitive for majority of managers, who would be willing to invest in minimum viable product at the very least. Moreover, our model assumes that the product would 100% be demanded by the market as long as it is produced with required value proposition, which is rarely realistic for a startup. Of course, in real life, product desirability needs to be tested first, which means investment in early product design to create and test a minimum viable product (MVP) is necessary. In order to test the robustness of our optimal strategy in the light of these issues, we have tested the same scenarios by imposing constraint in form of a minimum required investment in the MVP in the beginning of a simulation (not shown, available upon request), and found that it doesn't alter the optimal path configuration. In other words, the qualitative path of the optimal strategy requires pre-investment in operations early on before (or at least in parallel with) maximum investment in product design. Next generation of the model or future research could investigate the uncertainty associated with demand and assess its effect on optimal path. We hypothesize that there will be no fundamental changes to our findings, since basic correlation between product design obsolescence and operations capabilities drain (loop B3 in Figure 2), as well as asymmetric slope of degradation of both will require pre-investment in operations capabilities early on to ensure sufficient process quality and production capacity during "scale-it" phase.

8. Discussion and implications

Based on empirical case studies we have suggested a theoretical framework to identify optimal investment strategy in operational capabilities. Using System Dynamics approach, we have built a parsimonious simulation model to confirm our finding that *process centrality* of the value proposition determines the optimal timing of investment in ops and explore the optimal strategies and boundary conditions. We were able to demonstrate that simple two-period strategy (nail it then scale it) is the optimal strategy for pure product or process centric value propositions. For the mixed value proposition, a more complex three-period strategy where operational capabilities need to be pre-built before attending to product design proves to be superior.

Returning to our database of cases, we can now apply some directional insights from the model to suggest revisions to investment strategy of companies form our case studies. For companies with value proposition contingent on excellent quality, where the core value is in combining innovative product with quality underlying process (NxStage, Tesla, MediTech), the investment in operational capabilities should have been planned concurrently with product design features as indicated by red arrows (see Table 4). For companies such as Novaconfort, where the value proposition is an excellent process and SkinnyGirl, where the brand determines product demand and operational capabilities are needed to deliver the value proposition, ops should have been built from the very beginning with full focus on achieving the excellence.

Table 4. Suggested revisions of investment strategy for case studies

	Investment in Ops during:		
	Innovative Idea	Product Design	Pilot Sales
Sale or Refinance/pivot under duress		←	**Tesla (Roadster)** safety critical innovative product
		←	**MediTech** safety critical innovative product
Rise then fall or stagnation	NxStage **safety critical innovative product** →		
	←	Novaconfort **process**	
	←		SkinnyGirl **brand**

Insights from the model allow us to generalize the results and suggest the guidelines for optimal policy of investment allocation. Specifically, for a value proposition combining product features with quality process, early focus on operational capabilities (before investing in specific features) allows pre-building the launch pad for a product or a service immediately after the design is complete. The intensity of such investment in ops depends on how much value proposition depends on quality of the underlying process vs. design features, but characteristics of the environment (sensitivity of market price to value proposition, relations between investment in product design and ops and quality of product and process) moderate the effect. The model based simulation calibrated to a specific case should be used to evaluate the specific strategic decisions and establish confidence interval. The model we have built and used in this work is fully documented in Appendix A. Model Documentation. While intentionally built as a very general model without any particular details, it captures the core dynamics and can be used as a foundation for a more comprehensive model with as many additional data as necessary.

9. Conclusions and future work

Using extensive fieldwork we have developed the framework linking timing and intensity of investment in operational capabilities with performance of early startups mediated by process centricity of value proposition. We have further identified core dynamics explaining this effect using simulation of a dynamic model capturing the investment decisions of startups. We confirmed the delicateness of the balance between investing in ops early vs. investing in the future. The tipping point between lackluster and great performance is easy to miss given the financial constraints of early startups and is highly contingent on the type of the value proposition and the characteristics of the environment.

If the investment strategy is simple – "nail it first, and then scale it" – the *process centrality* defines the best strategy. Specifically, if value proposition is a process, while specific product can be defined later, such as when a firm has either know-how, patented IP for processes, rather than products, or inherited process capabilities from the parent company, the earliest investment in Ops (during *Innovative Idea phase*) allows for strong value proposition and is crucial for survival and high performance of a company. If value proposition is a product created and delivered through excellent Ops, which is the case of critical hardware, multisided software platforms, and safety critical goods, such as medical, aero, auto, investment in Ops during *Product Design phase* guarantees that enough product features are supported by needed ops to deliver value proposition. If value proposition is a product created and delivered through ad hoc experimentation, such as high tech consumer goods, services, apps/software, then early Ops are less relevant, since pilot sales can be managed through ad hoc experimentation and market success is achieved through investment in Ops much later (during *Pilot Sales Phase*) to ensure stable product features.

If we consider more sophisticated investment strategy, that is flexibly allocating cash between investment in product design and operations capabilities, the optimization suggests

three main phases – pre-build Ops, then invest in Product Design, and then scale it by switching all investment to operations capabilities with the exception of a fraction needed to compensate the obsolescence of product design. We didn't impose any constraint on the distribution of investment between product design and ops capabilities. The fact that in optimal strategy each phase requires almost 100% to either product design or ops capabilities is the indication that mixing investment objectives at any point in time doesn't provide any benefits, and focused approach is superior. This strategy is very similar to "nail it first, and then scale it", but with initial pre-building of Ops, which is necessary to ensure enough quantity can be produced once the product design features are perfected. This result seems to be most controversial for any startup manager, who generally tends to invest heavily in product design first to fix the MVP and secure first customers. While our simulation suggests that such strategy is also feasible, it is not optimal and can be improved by pre-building Ops from the very beginning. Of course, this assumes no uncertainty about product demand and perfectly elastic demand curve -- market big enough to consume any quantity of product or service a company is capable of producing at the right price.

Our framework and model capture the main patterns of operational capabilities investment strategies of early stage startups. However, we have made certain assumptions that need to be tested in the future research in order to ensure robustness of our findings. Specifically, the effect of competition might bring different incentives for companies building new value proposition. It might be expected that firms might need to rush to the market in order to capture early customers, thus too much perfection although desirable in ideal case of single firm market might not be warranted when competition is included. Also, we haven't assumed the possibility of multiple rounds of investing. While our endogenously generated revenue stream as a function of value proposition fit to the market might be considered as a proxy for consequent rounds of financing, it is not ideal proxy, as large cash inflow from new round of investment might have

stimulating effect on performance and give a company enough time to reorient and correct its earlier strategic mistakes. Also, we have simplified production as one step process, which obscures multiple processes involved and delays associated with manufacturing a specific value proposition. While we expect it to not affect our findings (the logic of relation of investment timing in Ops as a function of process centrality), specific industries might have additional patterns that we missed. Finally, we haven't explored the stochastic landscape of decision making. While random variations that might correct our proposed actions (such as more wealth of founders allowing for extra errors or unusual access to resources) do not invalidate our framework, which is aimed at covering typical patterns, potential insights might be gained from systematic treatment of stochastic nature of main events.

We present here a theory that although grounded in several empirical cases now needs to be tested through data collection from larger population of startups and we welcome any future research aimed at testing and expanding our framework and models.

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Appendix A. Model Documentation

The model has been designed using System Dynamics principles (Sterman, 2000) and implemented in Vensim.

```
Average Capabilities Relevance Time=
         120
   Units: Month
   Average duration of relevance for operational capabilities

Average Design Competitiveness Time=
   12
Units: Month
Average duration of relevance for product design

Capabilities and Product Design Correlation=
   0.5
Units: dmnl [0,1,0.01]
Correlation between product design and relevant features. Higher
         number means stronger drain of ops when features retire.

Capabilities Erosion=
   MIN((Operational Capabilities-Initial Operational Capabilities)/TIME
STEP,
    (Operational Capabilities-Initial Operational Capabilities
   )/Average Capabilities Relevance Time+Product Design Drain*Capabilities
and Product Design Correlation
)
Units: $/Month
Reduction in operational capabilities due to depreciation or
         loss of relevance

Cash to Experiment=
   IF THEN ELSE(Time<Spending Period, Initial Investment/Spending Period,
0)+
Revenue*Fraction of Revenue to Experiment
Units: $/Month
Total cash available to either improve design features or
         acquire operational capabilities

CES r=
   -1
Units: dmnl [-10,0.01,0.01]
r=1 -- perfect substitutes, r=0 -- Cobb-Douglas, r=-Inf --
         perfect complements

Dollar=
   1
Units: $
The value of one dollar

Factor Productivity=
   5
Units: widgets/Month
```

```
   Productivity of 1 unit of operational capability

   Fraction of Cash to Increase Product Design=
      IF THEN ELSE
        (Time >= Time to Begin Ops Investment,
          MIN(1, Product Design Drain/Cash to Experiment+Product Design
Improvement Fractional Rate
   *(1-Product Quality)),
          1
        )
   Units: dmnl
   Current fraction of cash used to improve product design

   Fraction of Revenue to Experiment=
      0.5
   Units: dmnl

   Initial Investment=
      350000
   Units: $ [0,1e+006,10000]
   Initial external investment available

   Initial Operational Capabilities=
      100
   Units: $
   Initial operational capabilities as represented by "garage
            facilities" of founders

   Initial Product Design Quality=
      100
   Units: $ [?,?,0.01]
   Initial product design features as represented by innovative idea

   Min Quality=
      1e-020
   Units: dmnl

   Operational Capabilities= INTEG (
      Ops Spending-Capabilities Erosion,
            Initial Operational Capabilities)
   Units: $
   Composite Operational Capabilities as represented by maturity of
            manufacturing processes, value of supply chain partners etc.

   Ops Spending=
      Cash to Experiment*(1-Fraction of Cash to Increase Product Design)
   Units: $/Month
   Investment in ops capabilities

   Price=
      EXP(-Steepness of the Price curve*(1-MIN(1,Value
Proposition)))*Reference Price
   Units: $/widget
   Price for unit of goods

   Process Quality=
```

```
      MAX(3*(1-Expanded X)^2*Expanded X*P1+3*(1-Expanded X)*Expanded
X^2*P2+Expanded X
   ^3, Min Quality)
   Units: dmnl
   Relative quality of a process on a scale 0 to 1

   Process Quality Yield=
      1
   Units: dmnl [0,1,0.01]
   Yield of investment in operational capabilities

   Product Design= INTEG (
      Product Design Spending-Product Design Drain,
            Initial Product Design Quality)
   Units: $
   Composite Product Design features, as represented by functions,
            appeal etc.

   Product Design Drain=
      (Product Design)/Average Design Competitiveness Time
   Units: $/Month
   Reduction in product design features due to obsolescence

   Product Design Improvement Fractional Rate=
      0.01
   Units: dmnl [0,1,0.01]

   Product Design Spending=
      Cash to Experiment*Fraction of Cash to Increase Product Design
   Units: $/Month
   Investment in product design features

   Product Quality=
      MAX(3*(1-Expanded X 0)^2*Expanded X 0*P1 0+3*(1-Expanded X 0)*Expanded
X 0
   ^2*P2 0+Expanded X 0^3, Min Quality)
   Units: dmnl
   Relative quality of a product on a scale 0 to 1

   Product Quality Yield=
      1
   Units: dmnl [0,1,0.01]
   Yield of investment in product design

   Production power=
      0.5
   Units: dmnl [0,1,0.01]
   Exponent of production function adjusting the responsiveness of
            the output as a function of ops capabilities

   Quantity of Production=
      Factor Productivity*(Operational Capabilities/Dollar)^Production power
   Units: widgets/Month
   Production of goods as a function of existing ops capabilities

   Reference Ops=
      100000
```

```
Units: $ [0,500000,1000]
Value of investment in operational capabilities at which full
         process quality is achieved

Reference Price=
   500
Units: $/widget
Full sales price of the product if the full value proposition is
         achieved

Reference Product Design=
   100000
Units: $ [0,500000,1000]
Value of investment in product design at which full product
         quality is achieved

Revenue=
   Price*Quantity of Production
Units: $/Month

Share of Product Quality in Value Proposition=
   0.9
Units: dmnl [0,1,0.01]

Spending Period=
   30
Units: Month

Steepness of the Price curve=
   10
Units: dmnl [0,10,0.1]
Responsiveness of sales price to value proposition

TIME STEP  = 0.0625
Units: Month [0,?]
The time step for the simulation.

Time to Begin Ops Investment=
   0
Units: months [0,120,0.1]
Time to begin investing in operational capabilities

Value Proposition=
   (Share of Product Quality in Value Proposition*Product Quality^CES r +
(1-
Share of Product Quality in Value Proposition
   )*Process Quality^CES r)^(1/CES r)
Units: dmnl
```