

# Operations Management Opportunities in Technology Commercialization and Entrepreneurship

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The field of Production and Operations Management (POM) is increasingly perceived as a rigorous but narrow field, antiquated and not very relevant to the current challenges and concerns of managers in job-creating growth companies vital to our economies. I argue that a narrower positioning of POM in the past is responsible for its perceived limited utility to growth firms and global economies. POM at its core is about “doing more with less,” which is very well aligned with the context and needs of resource-constrained entrepreneurial companies. My discussion is focused on how the research paradigm of POM is and can be relevant to meeting the emerging challenges of growth companies of tomorrow. Specifically, I examine how POM can help meet the needs of these organizations to become scalable and sustainable. The objective is to stimulate thought and discussion and encourage early-stage POM scholars to seriously consider the contexts of technology commercialization, entrepreneurship, and growth companies as avenues for future research.

*Key words:* technology commercialization; innovation; entrepreneurship

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## 1. Introduction

The “Kellogg Operations Workshop” is a biennial conference organized by the Kellogg School of Management to bring together a variety of scholars and review some of the latest research in greater depth than in the national conferences. At one of the first meetings of this workshop in 2002, the participants were addressed by the then dean of the Kellogg school. The dean good-naturedly remarked that he identified with the audience because he himself had set out to pursue his Ph.D. in Operations nearly two decades ago. However, his doctoral committee members had advised him that there was not much of a future in Operations and he should consider switching to other promising areas. That is how he ended up specializing in marketing and eventually became the dean at one of the leading management schools!

Researchers who interact with senior faculty from other disciplines in their school of business/management may have had similar experiences of Production and Operations Management (POM) being perceived as a rigorous but narrow field, antiquated and not very relevant to addressing the current societal challenges and concerns of senior managers in job-creating growth industries vital to our economies. I argue in this piece that the issue is one of framing—a narrower positioning of POM in

the past is responsible for its perceived limited utility to growth firms and global economies. POM at its core is about “doing more with less,” which is very well aligned with the context and needs of resource-constrained entrepreneurial companies. In the past two decades, POM has been focused on serving the needs of larger companies such as overhead reduction and waste elimination, but the POM concepts and methods are equally applicable and adaptable to smaller companies in more dynamic, high-growth environments without as much accumulated waste or legacy inefficiencies. My objective in this piece is to discuss the central challenges of growth and value/job creation confronting countries and companies and how the research paradigm of POM is and can be relevant to meeting these challenges. I conclude with an agenda of research questions that can help make POM more impactful to growing companies. This “perspectives piece” is by no means an exhaustive review of any area of POM, but it does contain some discussion of current research that helps point in the direction of increasing relevance of POM for growth companies. There have been other authors and papers, as early as Ackoff (1979), that have underscored the need for a “comprehensive re-conceptualization” of the Operations field/methodology to increase its impact and relevance. My key objective is not only to stimulate

thought and discussion, but also to encourage early-stage POM scholars to seriously consider the areas of technology commercialization and entrepreneurship as opportunities for future research and make contributions that help improve the success rate and productivity of organizations in these domains.

## 2. Emerging Challenges of 21st Century Countries and Companies

Productivity advances associated with the industrial revolution helped Western countries create substantial wealth and prosperity. A virtuous cycle of job creation and goods consumption ensued, resulting in significant standard of living improvements in North America, Western Europe, and eventually Asia. As diminishing returns confronted the productivity curve, further cost improvements required locating operations off-shore, leading to an era of slower growth, higher unemployment, and anxiety in the developed economies. While the development of the Internet tempered this trend and created opportunities, finding robust sources of growth continues to be a cause for concern.

The emerging economies of Asia-Pacific benefited somewhat from the movement of production operations to their countries, but they also face their own unique challenges. Widespread and extreme poverty coupled with the lack of a strong infrastructure constrains the sustainable development and growth of these countries. Unconstrained consumption of goods threatens environmental degradation and the possibility of global climate disruptions. A continual increase in the standard of living of all inhabitants of planet Earth is becoming difficult. There is a need for different approaches and new ways of thinking to realize sustained and sustainable wealth creation for all global citizens.

The unemployed (especially in developed nations) increasingly realize that they need to think and act “entrepreneurially” if they are not to be at the mercy of profit-maximizing major corporations. This means embracing risk and capitalizing on opportunities to create and sell new offerings that satisfy previously unfilled market needs, thereby creating robust revenues and profits. There is also a growing consensus that we need to benefit from the discovery, development, and commercialization of new technologies for the growing global prosperity to not threaten the natural environment, climate, and ecosystems. Thus entrepreneurship and technology commercialization are areas that have gained social importance, but have been under-studied by the scholarly community in general and the POM research community in particular (Shane 2006). I argue that the underlying paradigm of POM is very much relevant to the management of

technology commercialization and entrepreneurial organizations.

## 3. POM and Entrepreneurship

The terms “entrepreneur” and “entrepreneurship” are used in different settings with somewhat different connotations. For instance, entrepreneurship is used to refer to self-employment, opportunistic business growth, technology-driven startups, and even new business spinoffs within larger firms (Shane 2006). In teaching managerial classes, the Harvard business school definition seems to have taken hold: “Entrepreneurship is the pursuit of opportunity beyond the resources you currently control” (Stevenson 2000). My focus here is on early-stage firms (in their life-cycle) with high-growth potential.

The field of entrepreneurship has historically been considered an intellectual backwater that does not lend itself to a dynamic current of theory generation and testing. There are so many variables influencing the success of new ventures that scholars wonder if it is possible to develop testable theory that can predict the success of new ventures. However, at a societal level, entrepreneurship has steadily grown in importance, with more capital dedicated to it and some spectacular examples of wealth creation during the last decade that has captured the imagination of the general public as well as investors (Gompers and Lerner 1999). Successful entrepreneurs are seen as role models and societal heroes. International markets and economies are also teeming with entrepreneurs, especially in emerging markets where the workforce is young and willing to take risks (Acs et al. 2004, Economist 2010). Despite the many challenges of theory generation and validation, entrepreneurship can no longer be ignored by academics, and we must improve our understanding of this socially valuable area.

There has been a growing body of scholarly work relating to entrepreneurship, and it tends to be quite disconnected and inter-disciplinary, ranging from economics to sociology to finance to organizational behavior. Each of these areas shines the light on one aspect of entrepreneurship, still leaving significant voids on how to manage the operations of entrepreneurial firms. I now briefly review the body of inter-disciplinary literature that has contributed to the current understanding of entrepreneurship.

Research from the economics perspective has looked at the economic impact, incentives, and rationale for entrepreneurship. Questions that have been raised include the following: (i) Does entrepreneurship produce robust economic growth or how many jobs do entrepreneurs really create? (ii) Do tax cuts stimulate entrepreneurship? (iii) Why do entrepreneurs work so hard for so little pay and why are

some ethnic groups less likely to be entrepreneurs? There have been papers that have also looked at whether small entrepreneurial firms are more innovative than larger corporations and which entrepreneurial ventures are most likely to survive and grow, although the findings are far from conclusive. A review of this work is found in a number of papers, most recently by Parker (2005) and Minniti and Lévesque (2008).

Capital is critical to the founding and growth of entrepreneurial firms, so a significant literature on new venture economics and finance has developed over the past few decades (Gompers and Lerner 1999). Besides looking at the role of capital constraints in forming companies and the success of loan guarantee schemes in providing credit to new enterprises, researchers have always looked at the reasons for the significant rise in venture capital, including decreases in capital gains tax rates, easing of pension investment restrictions, and industrial and academic R&D.

A growing stream of work in the organizational behavior area and the Academy of Management/Strategic Management communities studies the paths to ownership and social influences and behavioral traits of entrepreneurs and how they differ from administrators in large corporations. The *Management Science* focused issue on entrepreneurship presents some examples of this body of work (Shane 2006). While this perspective is more detailed than the economic and financial views on entrepreneurship, it still focuses on the entrepreneur and his/her traits, influences, and motivations rather than the work and processes of entrepreneurship.

One of the key distinguishing challenges of an entrepreneurial venture is managing under severe resource (or input) constraints. An entrepreneurial manager's prime concern is to grow the outputs without growing inputs or build a company in the absence of much money and talented people, so in this regard the POM paradigm can come in handy. POM, at its core, is about doing more with less (getting the most high-quality outputs with the fewest inputs or grow what economist called total factor productivity). In the past few decades, POM has been focused on minimizing waste (input), especially in large corporations, where over a period of time, there is significant bloated overhead that offers opportunities for profit and speed improvement. While entrepreneurial companies are not typically associated with such inefficiencies, they do face other operational challenges—a primary one being growing and scaling in the absence of adequate resources.

To be relevant to the entrepreneurial community, POM must help improve and deepen our understanding of the concept of scalability. Put simply, scalability is the ability to grow revenue and/or output with the

same or fewer costs (inputs). In economic terms, this corresponds to an increase in total factor productivity (TFP).

The scenario facing an entrepreneurial firm may be described as follows. Typically, when a company is founded by a group of motivated and bright individuals, the founding team is involved in most aspects of the company's operations in the early days of the firm. However, as the company grows, it must hire new employees, because the founding team is capacity constrained and does not have the bandwidth to be involved in all aspects of the company operations. Coordination challenges emerge, and the firm finds it hard to meet its milestone targets. Even if the firm was successful in launching one successful product, it faces great difficulty in creating repeatable and predictable results in terms of a line of successful products. On the financial dimension, costs tend to grow faster than the revenues, eroding margins and worsening cash-flow constraints. Many an entrepreneurial start-up faces this scalability predicament, including the new wave of companies launched in the clean-energy space (Woody 2010).

The transition from craft production to mass production helped make manufacturing much more scalable during the 20th century. Specifically, core POM techniques like bottleneck management and line balancing helped increase the total factor productivity of companies and nations, resulting in a large growth in Gross Domestic Product per capita, especially in developed countries. Most of these economies are now facing a shift to information and knowledge-intensive services. Some of these services are labor intensive and not very scalable.

Scalability challenges in services as a whole, and entrepreneurial firms in particular, are often due to a lack of systematized procedures and practices that POM background and process-orientation potentially yields. A typical entrepreneurial firm is not only unable to realize scale economies but also misses the opportunity to benefit from prior learning and experience, resulting in higher costs. In addition, the firm may also face an elevated level of risk due to lack of controls in developing and launching products, as illustrated by the pains experienced by Dell Computer in its earlier years (Krishnan and Bhattacharya 2002, Thomke et al. 1999). However, formal processes are often associated with more established companies. Some entrepreneurs even consider "process" a bad word in their companies due to the organizational rigidity, inertia, and bloat associated with them. Clearly, entrepreneurial firms do not have the resources to invest heavily in codifying and enforcing processes. The challenge is to realize the scalability benefits of processes without incurring the costs and drawbacks.

With appropriate, flexible, and finely-tuned processes, an entrepreneurial firm can not only do more with less but also build a basis for sustainable competitive advantage. This is due to the fact that processes are harder to reverse engineer and could help develop a distinctive capability that translates to customer loyalty and more enduring profitability. Southwest Airlines offers a good illustration of how operating processes can help build competitive advantage. With its highly streamlined passenger boarding and flight maintenance processes, Southwest has been able to significantly reduce its flight turnaround time and increase the number of flights and passengers it carried. This gave Southwest Airlines both a niche in point-to-point travel and an enduring competitive advantage due to better processes resulting in lower costs and better on-time performance for a number of years since its inception (Gittell and Oliva 2002). Consequently, Southwest Airlines, with its process excellence, has been (at least till 2010) one of the rare exceptions in the airlines industry—a consistently profitable and shareholder value creating growth company.

Scalability for an entrepreneurial firm is also about building and profitably utilizing organizational and technological capacity amidst environmental complexity. Both Southwest Airlines and Dell illustrate how the founding entrepreneurs tackled the problem of scalability/capacity utilization in the face of declining prices and uncertain (raw material) costs. Southwest managed to control the cost of capacity with faster turnaround times, while Dell sought to increase its component inventory turns to confront component price deflation and perishability. Both of these examples show the role and relevance of operations in helping firms grow their businesses without compromising margins. While it may be hard to identify one or even a few solutions that fit all companies and environments, we need a sharper focus on scalability and how it may be achieved in different industry environments. Our state of knowledge with respect to entrepreneurial firms is fairly rudimentary in that we lack an understanding of the underlying variables and their inter-relationships that characterize these complex environments. In today's socio-economic environment, entrepreneurial firms face so much turbulence and uncertainty that they need concepts and methods to manage complexity. As Jaikumar and Bohn (1992) note in the context of manufacturing, static approaches of the past may not be adequate to manage the complexity associated with dynamic environments. We need new research to advance our state of knowledge of entrepreneurial companies and their challenges.

Entrepreneurial firms, by their very nature, are growth focused. This is only partly because they are

at an earlier stage of an organization's lifecycle with a lot of room to grow. Their stakeholders (investors, founders, and employees) also expect them to grow. Achieving sustained and sustainable growth is often a challenge. While the notion of growth by mergers and acquisitions (inorganic growth) has been studied at length by colleagues in the strategic management community starting with the classic work of Penrose (1959), the operational challenges of sustainable internal or organic growth is not so well understood. POM researchers have begun to make some headway in this area. In an analytical model, Joglekar and Levesque (2009) examine capital acquisition and resource allocation decisions across successive stages of an entrepreneurial firm's growth. Specifically, they focus on a startup firm faced with staged venture financing and significant R&D and marketing expenses, and the firm valuation is increased by product quality and market growth. The key decisions considered are the timing of acquisition of working capital, and how the acquired capital should be distributed between R&D and marketing to maximize firm valuation. Their results provide guidelines for budgeting R&D and marketing expenses as a percentage of revenues. Other papers have begun examining how knowledge and experience can help entrepreneurs make decisions such as opportunity assessment in a more rigorous manner under uncertainty (Bailey and Gaimon 2010, Levesque and Maillart 2008).

I refer to the entrepreneurial firm's ability to achieve enduring growth and competitive advantage as sustainability (to be contrasted with environmental sustainability that I address later in the paper). As a firm grows, it must make a number of decisions and take a number of actions that preserve, if not improve, its distinctive advantage. A key challenge for firms is how to continue to grow while sustaining their entrepreneurial capabilities, intimate customer relationships, and flexible structure. Although the topic of sustainable competitive advantage has been extensively studied in the strategic management community, resulting in concepts such as the resource-based theory of the firm, not much is known about how a firm can achieve sustainability when it has very limited resources in the first place. By building unique operational processes and routines, like in the case of Southwest Airlines, a firm may be able to build competitive advantage that is hard to imitate at least for a period of time.

In summary, the key goal of an entrepreneurial company is to become a scalable and sustainable company that can grow revenues faster than costs in addition to building and sustaining its competitive advantage over time (see Figure 1). POM research should be able to help firms navigate to this top-right quadrant, which makes these firms (in the words of



**Figure 1 Scalability and Sustainability as Two Dimensions of Firm Performance**



the legendary investor Warren Buffett) “businesses with economic castles protected by unbreachable moats.” For some companies (especially those that start with a product business model), like firm A in Figure 1, the challenge is to build a sustainable competitive advantage while protecting their high gross margins. For others (especially those that start with a services or customized products business model), like firm B in Figure 1, the challenge is to become more scalable while sustaining their competitive advantage in terms of intimate customer relationships. Specifically, when their offerings require production, they may be able to draw on the notion of micro-factories, which allow small production scale and offer flexibility (Anderson 2010). By understanding what makes processes effective and agile, POM can help entrepreneurial firms achieve scalability and sustainability. Indirectly, this approach increases the odds of success of entrepreneurial firms, ensuring social welfare through more productive use of capital and gainful employment for professionals.

#### 4. POM and Technology Commercialization

With the maturing of manufacturing, companies large and small are looking to other areas that offer opportunity for significant value addition and growth. At the same time, advances in sciences and engineering are producing significant new discoveries and technologies such as in genomics, stem cells, renewable energy, and networked information technology. The key challenge for firms is to convert these discoveries into viable offerings that benefit customers as well as innovating firms. Technology commercialization refers to the translation of technological capabilities into beneficial products and services that increase profit and/or social welfare. Sources for such technological solutions include not only the university and government research labs, but also the vast array of individuals accessible through the Internet (Von Hippel 2005).

Technology commercialization entails the sourcing of technologies, adding value to make them viable products and services, and launching these offerings to the marketplace. There are clear parallels to the manufacturing environment in the sense that technologies are analogous to manufacturing raw materials. Much like the manufacturing supply chain, there is the technology supply chain comprising suppliers such as inventors and research laboratories. However, there are some differences. Technologies are much more risky and in a state of flux than manufacturing raw materials. Readiness assessment becomes more challenging for commercializing technology than traditional manufacturing. In addition, the technology risks must be managed alongside conventional market and environmental risks. There are tools such as the Technology Readiness Levels (TRL) framework developed at the Department of Defense that can offer a good starting point (NASA Technology Readiness Definitions undated), but more research is required to facilitate the scouting for technology in non-defense settings.

The growing sophistication of discovered technologies and the rising costs of commercialization may require firms to collaborate in the development of new offering by pooling their resources and entering into resource-or cost-sharing arrangements. However, commercialization that occurs jointly between companies presents new sets of challenges. While inter-firm collaboration enables each firm to focus on what it does best and achieve certain economies of specialization, it also introduces issues associated with the alignment of decisions and incentives that have to be managed alongside conventional performance and timing uncertainties of single firm technology commercialization. Bhaskaran and Krishnan (2009) formulate the problem of commercialization occurring across firms specifically examining the implications of two collaboration mechanisms found in industrial practice, investment sharing and innovation sharing. Their analysis shows that investment sharing plays an important role in environments with higher levels of technology uncertainty, and innovation sharing produces better products and profits when the collaborating firms are more “efficient” in working together. Much more research is needed in this context of multi-firm technology commercialization to understand how to manage inter-organizational collaborations. In particular, product and system architecture can be a key concept that can help manage the translation and commercialization of technology. Specifically, modular product/system architecture can help attenuate the complexity by decoupling the design of component modules and facilitating distributed development and production (Arora et al. 1997, Ramachandran and Krishnan 2008).

Projects are the key vehicles for translating technologies into viable offerings, and project management is gaining greater prominence in organizations (Peters 1999). Traditional project management in construction-type settings allowed for relatively easier administration of project workers, where managers could specify, define, and schedule project tasks clearly. In knowledge-intensive settings such as technology commercialization, project managers face challenges that arise from the increasing risk, knowledge intensity, and autonomy of contributors. Much of the information about project activities and tasks is abstract and resides in the heads of individual contributors, making it harder for managers to specify and subdivide work. The increasing complexity and specialization required for technology commercialization projects increases the power wielded by project professionals. This has made it harder for managers to dictate to individuals as easily as they could in a traditional hierarchical organization. The greater flexibility and discretion wielded by individual project team members makes managers more vulnerable to the behavioral quirks and limitations of these workers (Loch and Wu 2007). Unlike the case of manufacturing, the output in these new settings is not easily measurable or fully contractible. Future POM research must help understand how to manage the behavioral quirks of project workers, such as their tendency to leave more work for later completion (Krishnan and Loch 2005). Research must help managers come up with mechanisms and incentives to encourage workers to engage in their task in an effective and efficient manner (Wu et al. 2009).

Production and operations management must also help develop a better understanding of the information-intensive contexts in which technology commercialization occurs today. During the past century, we have a significantly improved understanding of manufacturing processes, which has helped achieve an order of magnitude improvement in productivity. Information and knowledge-intensive activities are the areas of growth, and information-technology is changing the landscape of business. One of the central challenges especially in information and knowledge intensive environments is coming up with the right way to measure the output of workers. Unlike a manufacturing environment, where throughput can be counted at the end of a production line, outcomes matters more than the outputs in the case of information and knowledge intensive environments. Consider the following example of an automobile development project. A developer may come up with a design that significantly improves the side-impact collision strength of the product. While this may increase the durability of the vehicle and reduce the number of vehicles (output) sold in the short to

medium term, it has the potential to enhance the reputation of the company and gain market share in the longer term. Counting outputs is not adequate in this setting (as in many other service settings), and this illustrates the central challenge of measuring and managing processes in knowledge- and information-intensive settings.

## 5. Conclusion

In summary, POM has a lot to contribute to the fields of technology commercialization, entrepreneurship, and growth-driven operations. The key is to recognize that POM is not just about having less but also doing more. By embracing a broader set of methodologies going beyond conventional optimization approaches—specifically including experimental and empirical methods—POM can develop a well-grounded theory of management of the entrepreneurial and/or technology commercializing firms especially in the context of information and knowledge work, where most such firms operate. Future POM research should help develop processes uniquely suited to the challenging context of small and medium sized firms. Research will remain sympathetic to our current professional dedication of efficiency, but should take an expanded view of input factors (including network capital and relationships), processes (including relations/incentives with and for workers), and outputs (deriving new products and markets from basic ideas and research), all within the very tight financial constraints characteristic of start-ups and small firms. POM can thereby help substantially improve productivity and create prosperity in this century as it did in the last century.

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