PART III

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PROCESS CAPABILITIES AND LEVERAGING ADVANCES IN SCIENCE AND TECHNOLOGY

Cheryl Gaimon, Manpreet Hora, and Karthik Ramachandran

1 Introduction

This chapter focuses on the role of operations managers who define the process capabilities that critically impact a firm’s competitive advantage. Process capabilities are embodied in manufacturing equipment, information technology (IT), workforce, distribution systems, materials, and procedures. For the purposes of this chapter, we establish two key characteristics of process capabilities. First, examples from managerial practice demonstrate how process capabilities drive the creation of new products, services, and business models as well as improvements in those that already exist. Second, these examples also demonstrate the importance of pursuing advances in science and technology to innovate process capabilities (Gaimon 2008).

The remainder of the chapter is devoted to developing a deep understanding of the research and managerial implications that lead to the successful innovation of process capabilities. We explore how advances in science and technology are pursued to innovate process capabilities in two contexts. In Section 2, we consider a firm that relies solely on its internal knowledge resources, whereas in Section 3, we consider a firm that relies on both internal and external knowledge resources. In Section 4, we suggest opportunities for future research. Implications to managerial practice are highlighted in Section 5. We conclude the chapter in Section 6. Consistent with the operations management orientation of this book, we generally focus on how advances in science and technology drive new process, as opposed to product, capabilities.

1.1 Process Capabilities and New Product Development

To successfully create new products, services, and business models, a firm must have a deep understanding of customer needs. Typically, market researchers obtain insights on consumer needs from surveys, focus groups, and feedback from sales workforce. However, while clearly important, a marketing-oriented focus is not sufficient to ensure success in the global marketplace. Rather, managers must have a systems-oriented perspective that pursues advances in science and technology in response to or in anticipation of the need for both new product attributes (marketing) and new process capabilities (operations) (Kim and Mauborgne 2015).

The key element of the systems approach is integration. Integration of product and process considerations reduces the likelihood that market research identifies product attributes for
which manufacturing processes do not exist. Advanced Micro Devices (AMDs) faced this chal-
gen when it was unable to manufacture a series of advanced CPU chips it had successfully
designed (Willcox 1999). Second, integration reduces the likelihood that the results from market
research do not fully exploit the firm’s unique process capabilities. Third, integration may sug-
gest constraints on new product attributes to reduce the costs and risks needed for new process
capabilities. By placing constraints on product design, Toyota manufactured the hybrid Prius in
factories already producing gasoline powered vehicles (Tilin 2005; Nonaka and Peltokorpi 2006;
Weber 2006). Fourth, constraining product design may be desirable to reduce the time and cost
of new product introduction. Automobile manufacturers reduce the time and cost to intro-
duce new models by relying on parts commonality and shared platforms (auto chassis) models
(Kubota 2015).

1.2 Process Capabilities and Profitability

Beyond creating new products, services, and business models, process capabilities improve the
profitability of a firm’s existing product portfolio (Mattioli and Maher 2010). Advances in
process capabilities reduce manufacturing costs by improving production efficiency (reduce
setup times, direct labor, and yield loss). In services such as banking, insurance, and healthcare,
advances in IT (referred to as the “machine tool” for services, Gaimon 2008) lower costs by
both reducing the time for and improving the quality of processing transactions (Porter and
Heppelmann 2014).

Advances in process capabilities, such as flexible manufacturing, also increase revenue by
allowing a firm to rapidly changeover from the production of one high-volume product to
another. This capability is particularly important in the pharmaceutical, electronics, and automo-
tive industries where the demand for new high-volume products is uncertain, product life cycles
are short, and high costs are incurred for new manufacturing facilities (Pisano and Rossi 1994;
Gaimon and Morton 2005; Clark 2015). Additionally, by reducing the time and cost of change-
over setups, flexible manufacturing provides the capability to economically produce a variety
of small-mid volume products “simultaneously” in a single facility (Gerwin 1993; Carrillo and
Gaimon 2002). At the extreme, flexible technology may enable mass customization (Gilmore
and Pine 1997).

In services, advances in IT enable a firm to customize services while adjusting their capacity to
manage demand variability (Aranda 2003). Manufacturers also increase revenue by bundling ser-
VICES with product offerings (Reinartz and Ulaga 2008). By leveraging IT capabilities, Caterpillar
earns premium revenue by offering customers real-time monitoring of heavy farm machinery
(Porter and Heppelmann 2014).

Advances in IT substantially impact a firm’s extended supply chain by transforming business
processes to enable real-time interactions among consumers, manufacturers, distributors, and
retailers. The pasta maker, Barilla, uses a sophisticated replenishment system to reduce demand
uncertainty, lower costs, improve time-to-market, and ensure consistent quality (Lee 2002).
Retailers such as Zara rely on real-time monitoring systems to rapidly replenish fast-moving
merchandise to reduce costs, improve revenue, and manage demand uncertainty (Harle et al.
2002; Bjork 2014). Airlines, hotels, and car rental agencies are exploiting advances in IT-based
process capabilities with “revenue management” (a form of business analytics that determines
both product availability and price to maximize revenue growth) (Talluri and van Ryzin 2006).

Lastly, advances in science and technology are particularly valuable because they may remain
proprietary. Imitation by competitors may be limited because the disassembly of a finished
good may not reveal the precise steps used in manufacturing (reverse engineering). Proprietary
processes are leveraged in industries ranging from chemical and pharmaceutical (Pisano and Wheelwright 1995) to fashion (Pisano and Shih 2012).

1.3 Recent Advances in Process Capabilities

Advances in science and technology profoundly impact a firm’s ability to provide new products, services, and business models and to improve those that already exist. Interactive communication technologies facilitate the real-time identification of major consumer trends (Bayus 2013). Advances in telecommunications technology and collaboration software integrate product and process development activities in diverse locations (Staats 2012). Rapid prototyping technology generates a large number of product and process concepts for further evaluation and testing, which reduces the cost and time to introduce new or to improve existing products and services, while increasing the likelihood of market success (Thomke 2001).

Recent advances in additive manufacturing (3D printers) allow a firm to offer custom products that were too complex and costly to produce with traditional manufacturing methods (The Economist 2012; D’Aveni 2015). However, while useful for high-end and low-volume custom products, advances in additive manufacturing that offer economies of scale are needed to economically produce low-price and high-volume commodity products (The Economist 2012).

Advances in robotic technologies reduce production costs so that firms can cost-effectively manufacture and distribute products worldwide to enhance their response to local customer needs and to reduce distribution costs (Hagerty 2015). Interestingly, even firms operating in countries known for low-cost labor are investing in robotics due to increasing wage rates (Markoff 2012). Retailers such as Amazon are introducing robotics in their fulfillment centers to meet increasing demand volume and to reduce order processing time (Love 2014). Nevertheless, advances in robotics and a deeper understanding of their applications are needed to reduce the investment cost, improve efficiency, improve fine motor capabilities, and enhance flexibility (Dou 2014).

1.4 Greenfield Versus Brownfield Change to Process Capabilities

To exploit advances in science and technology, a manager must decide whether to build a new manufacturing or service facility (greenfield) or to modify an existing facility (brownfield). According to Hargadon (2012, page 1), these terms “originated to describe the difficulties of modernizing existing factories relative to building new ones. Because brownfield factories were originally designed for particular modes of production, once major changes were needed, it was often easier to just find a green field to build a whole new factory than to upgrade an old one.”

We extend the above interpretation of brownfield versus greenfield to include IT which serves as the “machine tool” in service industries (processing, tracking, and distribution) and plays a critical role in manufacturing industries (integrating producers, suppliers, and customers) (Gaimon 2008). Therefore, in a greenfield approach, new process capabilities may be obtained by building a new facility or introducing a new IT system. In contrast, when using a brownfield approach, new process capabilities result from upgrading an existing facility or an existing IT system.

The decision to pursue a greenfield approach versus a brownfield approach to process innovation is complex. Typically, if existing process capabilities can be easily re-deployed or upgraded, both the cost and time required for the brownfield approach are lower and the performance outcome is less uncertain. Unfortunately, it is often extremely difficult to anticipate a firm’s ability to re-deploy or upgrade existing process capabilities. Moreover, the brownfield approach may limit performance improvement due to the constraints needed to ensure compatibility with existing manufacturing facilities or remaining legacy systems. In fact, Hargadon (2012) notes that
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many firms known for being highly innovative (Amazon, Google, and Facebook) benefited from introducing greenfield process capabilities, whereas established firms (GM) suffered from the constraints encountered when changing existing manufacturing facilities (brownfield).

The candy company Hershey’s introduced a greenfield IT system (Enterprise 21) consisting of software and hardware from multiple vendors to manage a wide range of process capabilities (Laudon and Laudon 2013). Enterprise 21 went live all at once and in all locations in mid-July 1999; simultaneously, existing IT systems were shut down. While 40% of Hershey’s annual sales occur between October and December, the greenfield system remained inoperable as of January 2000.

A great deal can be learned from the above example. Safeguards are needed to reduce the disruptions of implementing greenfield (or to a lesser extent, brownfield) process capabilities. For example, a manager may (i) rely on existing process capabilities as a backup until new processes are fully operational, (ii) perform extensive testing of new processes prior to full implementation, (iii) ensure workforce skills exist to operate and manage new processes, and (iv) have contingency plans in the event that new processes experience failure. In addition, (v) the appropriate timing strategy to innovate process capabilities is needed, as described next.

The speed with which a firm innovates its process capabilities (timing strategy) significantly impacts the cost, time, and performance realized (Carrillo and Gaimon 2000). Process capabilities can be radically changed either by building a new facility/IT system or by introducing a massive upgrade to an existing facility or IT system. Alternatively, process capabilities can be improved incrementally by introducing a series of smaller IT upgrades or smaller facilities. The incremental approach allows managers to exploit learning benefits to enhance the design, implementation, and overall performance of future changes in process capabilities (Carrillo and Gaimon 2000; Gaimon and Burgess 2003; Upton and Fuller 2004). The incremental approach also allows a manager to delay the full commitment to new process capabilities until uncertainties in future demand and advances in science and technology are resolved (Carrillo and Gaimon 2004; Burkitt 2015). Moreover, in practice, it is typically easier to manage the re-training and transition of the workforce when undertaking incremental improvements (Gaimon et al. 2011). However, the incremental approach may also slow the rate of performance improvement and reduce a firm’s ability to meet rapidly increasing demand. Finally, due to the loss in economies of scale, a series of incremental investments in process capabilities may be more expensive.

2 Managing Internal Knowledge to Develop Process Capabilities

In this section, we consider a project where a manager relies on internal knowledge resources to enhance process capabilities in order to offer new or to improve existing products, services, or business models. In general, this is referred to as a new product (process) development (NPD) project. Essentially, an NPD project is a knowledge-oriented job shop where novel advances in science and technology are created by a highly skilled workforce whose efforts are supported by sophisticated IT systems. Of course, beyond the workforce and IT systems, we also consider how the external marketplace and internal incentives drive a successful NPD project.

2.1 Integrating Product and Process Knowledge in a Single NPD Project

Overlapping activities of product and process design teams facilitate the integration needed for a successful NPD project (Section 1.1). Integration requires that newly developed knowledge be transferred between teams of highly skilled workers responsible for both product and process design. In the context of NPD, knowledge development (KD) is a form of induced learning
(deliberate activities are pursued and costs are incurred) in which product and process design teams generate knowledge about product attributes and process capabilities by performing problem solving activities including prototyping, simulation, experimentation, and testing (Argote 2013). Knowledge transfer (KT) between product and process design teams occurs when they participate in joint meetings, share documentation, or exchange information such as design drawings via telecommunications technology (Staats et al. 2011; Argote 2013).

Krishnan et al. (1997) were among the first to consider KT in NPD projects. To accelerate a firm's time-to-market, they suggest that the rate of KT from the product to the process design team should reflect: (i) the speed with which the product design converges to the final product attributes, and (ii) the nature of the problems that arise when process design decisions are made prematurely while the product design is evolving (Loch and Terwiesch 2005). However, since Krishnan et al. (1997) only consider the one-directional KT from a product to a process design team, they do not address the key problem of design for manufacturability. Moreover, given the focus on KT, the authors do not determine how a manager should pursue KD for each team during the NPD project.

More recently, Ozkan-Seely et al. (2015a) consider a manager who determines the rates of KD for a product and a process design team and the rates of KT between both teams (in both directions) throughout an NPD project. While the benefits from KD are instantaneous, the benefits of KT are lagged because of challenges faced by the source team to document knowledge and challenges faced by the recipient team to understand and apply knowledge (Szulanski 2000; Carlile 2002). Importantly, the authors capture the impact of absorptive capacity, which represents a firm's ability to recognize, assimilate, leverage, and deploy external knowledge (Cohen and Levinthal 1990). Specifically, empirical results on absorptive capacity are modeled as follows: (i) a more highly skilled team is better able to generate new knowledge from KD (Nonaka 1994; Carrillo and Gaimon 2004), and (ii) a recipient team benefits more from KT if the source team has more knowledge to transfer and if the recipient team has more knowledge to facilitate its application (Bhuiyan et al. 2004).

Ozkan-Seely et al. (2015a) describe their results in the context of Toyota's successful introduction of the Prius (Tilin 2005; Nonaka and Peltokorpi 2006; Weber 2006). The Prius differed from Toyota's other vehicles by using an electric motor in addition to the standard gasoline engine. Given the complex task of developing an entirely new system of electric motors, sensors, and other components, the initial level of knowledge for Prius' product design team was relatively small. However, by manufacturing the Prius in factories already producing gasoline powered vehicles, the initial level of process design knowledge was relatively large.

Toyota leveraged its process capability by front-loading KT to the product design team. Said differently, the Unit Production Technology Department transferred process design knowledge to the product design team at an initially large but decreasing rate over time. Therefore, early in the project, process design knowledge from Toyota's existing manufacturing capabilities provided direction for the product design team.

KD for the Prius' product design team initially occurred at a decreasing rate, reached a minimum, and later occurred at an increasing rate over time (U-shape). Early in the project, opposing forces drove Prius' product design team to pursue a large but decreasing rate of KD. The large rate was advocated to rapidly increase the initially small level of product design knowledge. But, since the early benefits of KT from the process design team were lagged, the product design team had incentive to delay higher rates of KD. Later in the project, as manufacturing process constraints were better understood (KT benefits were realized), Prius' product design team intensified KD, which occurred at an increasing rate, until final product attributes were established (fuel infrastructure, battery powered design, engine system). (KD for the Prius' process design team also
followed a U-shape. However, early in the project, the process design team pursued more KD than that of the product design team in order to accelerate the rate of KT.)

The Prius example highlights two key managerial insights. First, it shows how a manager leverages a high (or compensates for a low) level of product or process design knowledge at the outset of an NPD project. Therefore, the manager must carefully select the initial members of both teams, and must invest in training to ensure that the necessary skills are available for future projects. Second, the Prius example demonstrates the importance of reducing the time lag for the recipient team to benefit from KT. The lag may be reduced by: (i) selecting team members with cross-functional skills, shared work experience, and trust (Goh 2002); (ii) establishing incentives and rewards to encourage the source team to codify knowledge and the recipient team to absorb knowledge (Clark and Fujimoto 1991); (iii) providing IT-based communication and collaboration capabilities to both teams (Staats et al. 2011); and (iv) reducing NPD project complexity (Gaimon et al. 2011).

2.2 Derivative and Radical NPD Projects

Beyond the challenge to integrate product and process design knowledge, we must also consider how NPD differs for a derivative or radical project (Wheelwright and Clark 1992). A derivative NPD project incrementally improves the performance of a product that already exists in the marketplace. The gain in profit, the development cost incurred, and the time required to complete a derivative project are relatively small. In contrast, a radical product, service, or business model creates a new market based on fundamental advances in science and technology (Kim and Mauborgne 2015). While offering the greatest opportunity to generate revenue, a radical NPD project consumes expensive R&D resources over a long period of time and is risky since advances in science and technology may not lead to successful new products (Christensen 2013).

It is reasonable to expect that the rates of KD and KT differ for a derivative versus a radical project. First, due to similarities with existing product attributes and process characteristics, more knowledge resources are available at the outset of a derivative as compared to a radical NPD project. Second, due to its incremental nature, the time lag required for a recipient team to understand and apply knowledge received from a source team is smaller for a derivative as opposed to a radical NPD project. Consistent with Ozkan-Seely et al. (2015a), we expect that the manager of a derivative project (i) front-loads KT in both directions and (ii) while KD is U-shaped, both the product and process design teams pursue relatively higher rates early in the project. However, since Ozkan-Seely et al. (2015a) assume deterministic conditions, the impact of uncertainty in the radical NPD project is unknown. The next two sub-sections are devoted to analyzing the challenges of managing a radical NPD project.

2.2.1 A Radical NPD Project

The Big Dig tunnel construction project in Boston was a radical NPD project that faced several unforeseen engineering challenges, which led to a massive cost overrun (over 300%) and significant delays (Murphy 2008). More recently, the U.S. Federal Government undertook a radical project to create the portal known as healthcare.gov, to serve as the backbone of the Affordable Care Act. According to Pipes (2014), the successful introduction of healthcare.gov faced challenges due to “bad management, poor oversight, lack of communication, and intense political pressure (which) combined to produce a technology failure of epic proportions.”

The above examples demonstrate the delays and cost overruns typically encountered in a radical NPD project due to high degrees of uncertainty and complexity. Furthermore, the above
examples demonstrate that, even if eventually successful, a radical NPD project may require that
teams of highly skilled workers persevere through a series of intermediate failures in which pro-
ject costs and deadlines balloon beyond initial targets.

Wu et al. (2014) explicitly consider the impact of incentives on the outcome of a radical
NPD project. They assume the project is undertaken by highly skilled individuals who prefer
immediate gratification over long-term happiness. The authors show that this behavioral bias
may drive the rate of KD to be back-loaded (the rate increases over time throughout the project).
Interestingly, according to Goldratt (1984), when individuals procrastinate in the early stages of
a project and exert maximal effort closer to the project deadline, the project suffers from delays
and undue resource consumption. Taken together, the above results demonstrate the important
role of incentives as a driver of success in a radical NPD project.

2.2.2 Funding Radical and Derivative NPD Projects

Chao et al. (2009) analyze a portfolio manager’s allocation of funding between derivative projects
and a radical project. While derivative projects incrementally and continuously improve (by a
known amount) the revenue stream from an existing product, the radical project potentially
offers a large amount of revenue but consumes a considerable amount of R&D resources and is
associated with high levels of technical and market uncertainty.

Chao et al. (2009) show how two funding mechanisms, commonly used by NPD portfolio
managers, impact resource allocation. With the first mechanism, the manager receives a fixed
amount of funding (budget) for its NPD portfolio. Under variable funding, the portfolio man-
ger has the autonomy to control the allocation of NPD resources since the source of funding is
the continuous revenue stream obtained from derivative products.

Chao et al. (2009) find that, when a portfolio manager controls funding, larger investments
are made in derivative NPD projects as well as in the radical NPD project. However, autonomy
has a critical downside: the portion of investment in derivative projects increases by a greater
amount than does the portion of investment in the radical project. Therefore, a firm whose NPD
portfolio manager controls his own budgets risks underperforming in situations where radical
projects are necessary for long-term competitive advantage.

2.3 Investments in Technical Support

Beyond managing the highly skilled workforce, the NPD manager must also invest in IT such
as computer-aided design, rapid prototyping, and telecommunications systems with collabora-
tion software (Gino and Pisano 2006). Gaimon (1997) studies one such IT-worker system and
finds the investment in IT increases the desirability of employing a larger workforce. Therefore,
instead of the substitution of advanced technology for labor often observed in manufacturing, a
complementary relationship exists.

In subsequent research, Gaimon et al. (2011) consider how workforce knowledge should
be managed when a technology upgrade is introduced. The results offer important managerial
insights. First, if rapid improvements in IT are anticipated, then a firm’s increase in revenue from
an IT upgrade may not be sustainable since superior IT capabilities will be available to competi-
tors in the future. In other words, when the rate of technology advancement is high, the manager
of the IT-worker system cannot solely rely on an IT upgrade to remain competitive. Alternatively,
the manager may need to pursue a series of IT upgrades or rely more on advancing internal
workforce skills (which may remain proprietary).
Second, Gaimon et al. (2011) recognize that, if an IT upgrade provides a large advancement in capability, then higher costs are incurred from workforce disruption since existing skills become obsolete and new skills are required. Their results suggest that, to cost effectively pursue a large increase in IT capability, the manager of an IT-worker system should work closely with the IT vendor to enhance the rate of increase in revenue and to curtail the costs of workforce disruption by ensuring technical compatibility and by providing customer training.

3 Managing External Knowledge to Develop Process Capabilities

The complexity and scope of knowledge necessary to successfully introduce new products, services, and business models based on advances in science and technology has dramatically increased (Oxley and Sampson 2004; Cassiman and Veugelers 2006). As a result, many firms engage in cooperative agreements (alliances or partnerships) to access external complementary resources to generate new knowledge (exploration) or to leverage existing knowledge (exploitation) (Hoang and Rothaermel 2010). For example, Proctor & Gamble’s CEO stated that “we will acquire 50% of our technologies and products from outside” (Huston and Sakkab 2006). Naturally, depending on the nature of the alliance or partnership formed, financial resources may or may not be exchanged. In the remainder of this section, we consider three means by which a firm obtains external knowledge and the managerial implications of each.

3.1 Alliances in a Supply Network

Consistent with our operations management perspective, consider a firm’s alliance with partners in its supply network (including customers, suppliers, and service providers) (Yli-Renko et al. 2001). Leveraging an extensive database in the electronics industry, Bellamy et al. (2014) examine how a firm’s supply network enables it to develop and apply advances in science and technology. The authors explore the impact of (i) supply network accessibility (how quickly and effectively a firm can access different sources of knowledge from its network), and (ii) supply network interconnectedness (degree to which a firm’s network partners have supply relationships with each other).

Bellamy et al. (2014) empirically show that a positive relationship exists between a firm’s ability to benefit from advances in science and technology and supply network accessibility. Furthermore, the authors demonstrate that, with a high level of absorptive capacity (Section 2.1), a firm’s supply network interconnectedness provides greater benefits from advances in science and technology.

Unfortunately, many firms do not obtain the anticipated benefits from its supply network (IBM Report 2007). This is partly due to the lack of alignment among partners in knowledge sharing agreements. Hora and Dutta (2013) study the role of depth and scope in a sample of 728 alliance partnerships between biotech firms and pharmaceutical companies. Depth refers to the extent that a firm engages in repeated alliances with the same partner, whereas scope refers to the breadth of knowledge shared in the alliance. Empirically, the authors show that, by increasing alliance depth and scope, the commercialization success of advances in science and technology improve. In particular, alliance depth enables a manager to build trust and thereby reduce transaction costs, and alliance scope facilitates KT to reduce development costs.

3.2 Alliances with Competitors

Ironically, the knowledge that a firm needs may only be available from a competitor (Arora and Fosfuri 2003). Under coopetition, a firm forms an alliance with a competitor whereby both
firms simultaneously pursue competition and cooperation to launch new products, services, or business models (Brandenburger and Nalebuff 1997). Typically, a source firm (supplier) sells a portion of knowledge to his competitor (buyer) and later both firms compete in the same market (Anand and Khanna 2000). Coopetition occurs in many industries including automotive, electronics, and pharmaceuticals. Knowledge may be provided in the form of patents in addition to scientific or technical documentation. Samsung acquired patent rights from SanDisk and both firms used those patents to develop flash memory systems (Clark 2009). Toyota licensed its Prius hybrid technologies to Mazda, which plans to launch its own hybrid vehicle (Takahashi 2010).

3.2.1 Trade-Offs in Coopetitive Development

The revenue earned from selling knowledge to a competitor may compensate for the loss in proprietary value because it can be invested in other NPD projects (Brandenburger and Nalebuff 1997). Also, the supplier may benefit from the sale of knowledge if market response is uncertain (Appleyard 1996; Kulatilaka and Lin 2006). The buyer in coopetitive development also faces uncertainty regarding its own ability to integrate the supplier’s knowledge, and the actual value of the knowledge given the supplier’s opportunistic behavior (Gnyawali and Park 2011).

Interestingly, coopetition may be more lucrative than collaborating with a non-competing firm (Brandenburger and Nalebuff 1997). Loebecke et al. (1999) find that a buyer’s ability to integrate knowledge from a supplier critically impacts the performance of both firms. Managerially, this result suggests the advantage realized by a firm that forms an alliance with a competitor whose knowledge is highly related. Ozkan-Seely et al. (2015b) consider coopetition between a leader (knowledge supplier) and a follower (knowledge buyer). Preliminary results show that the price charged by the leader and the amount of knowledge purchased by the follower differ depending on whether uncertainty resides in the marketplace, the technical ability of the supplier, or the buyer's absorptive capacity (Section 2.1). This suggests that, before a firm acquires knowledge from a competitor, it must carefully assess the sources of uncertainty.

3.3 Acquiring Knowledge from Non-Competing Firms

Beyond external knowledge obtained from its supply network or a competitor, a firm may also acquire knowledge from a non-competing firm. Knowledge outsourcing occurs when a buyer acquires and integrates knowledge from an external non-competing supplier such as a consultancy. According to Couto et al. (2008), the rate of knowledge outsourcing is increasing, particularly in sectors including product development, engineering services, R&D, and analytic knowledge services. U.S. census data (BEA 2013) indicates that the GDP value added by knowledge-intensive firms that drive advances in science and technology has more than doubled between 1998 and 2012. For instance, firms such as InnoCentive (Lakhani 2008) have greatly expanded the role of the consulting industry. While the operations management literature on component outsourcing has led to a deep understanding of procurement to ensure efficient quality, on-time performance, reliability, information sharing, and trust building, Cachon and Lariviere (2005) found that, despite its prevalence in practice, the literature on knowledge outsourcing is limited.

Lee et al. (2015) use game theory to analyze the situation where, to meet the need for more knowledge, a buyer (she) may develop knowledge internally (KD) and/or may outsource knowledge from an external non-competing supplier (he). The knowledge purchased by the buyer is specified as a deliverable in the form of knowledge “output” which may include design drawings,
software, or a prototype. The fundamental questions addressed include the following: (i) What price should the supplier (leader) charge for outsourced knowledge? (ii) How much knowledge should the buyer (follower) develop internally versus outsource to the supplier?

The authors recognize that outsourcing may reduce the cost incurred by the buyer for internal KD (Carrillo and Gaimon 2000). However, the buyer’s benefits from knowledge outsourcing may be limited by the supplier’s high price and the buyer’s lack of absorptive capacity (Section 2.1). The supplier’s price is driven by, among other things, the amount of knowledge he has available versus the investment in internal KD the supplier must undertake to meet the buyer’s demand for outsourcing.

In a key result, Lee et al. (2015) show that a buyer always benefits if she has a higher level of absorptive capacity; but a supplier’s benefits are conditional. The authors also consider the situation where the buyer may not be certain of the extent to which her prior knowledge is applicable to meet her current needs; i.e., her project scope is uncertain. Counter to intuition from prior operational models, Lee et al. (2015) show that a buyer may benefit from project scope uncertainty because the supplier may be motivated to charge a lower price. Moreover, despite the lower price, the authors show that the supplier’s profit may increase because the buyer pursues more outsourcing. Therefore, an important insight is obtained: under the right conditions, both the buyer and supplier benefit from project scope uncertainty.

4 Future Opportunities for Research

In this section, we suggest directions for future research.

4.1 Leveraging Internal Knowledge

The research in Section 2 explores a manager’s use of internal knowledge for an NPD project. Much of that optimization research can be extended by explicitly recognizing the stochastic nature of revenue. This is particularly applicable for a radical NPD project (Chao et al. 2009). Empirical research is needed to better understand drivers of NPD uncertainty and how a manager can reduce the impact of uncertainty on time-to-market. Empirical and optimization research is needed to identify and exploit the complex relationships (grounded in organizational theory) among a manager’s investments in KD, KT, and technical support which drive the IT-worker system responsible for the NPD project. Moreover, empirical and optimization research is needed to explore the implications of successful NPD in relation to the often contradictory incentives of top management, mid-level managers, and the knowledge workers who directly create the advancements in science and technology.

In the context of portfolio management, Chao et al. (2009) determine the funding allocation between a radical NPD project and derivative NPD projects. However, they do not examine the funding allocation between product and process design activities. Said differently, an opportunity exists to study how early and late investments in product versus process design should be allocated among a portfolio of products. Additionally, Chao et al. (2009) do not capture a key opportunity realized when radical and derivative NPD projects are linked. In ongoing research, Xiao (2012) recognizes that a portfolio manager may benefit from transferring a portion of the knowledge developed while pursuing a radical NPD project to introduce a new derivative product. Although KT potentially reduces the (stochastic) gain in revenue if the radical project were successful, it also increases the current revenue stream obtained from the derivative project and reduces the risk of investing in an unsuccessful radical project.

The potential benefits realized by a manager who invests in technical support of a highly skilled workforce are explored in Gaimon (1997) and Gaimon et al. (2011). However, that research does
not focus on an IT-worker system in the context of an NPD project. Instead, it considers a manager who deterministically increases revenue by increasing output volume. Therefore, empirical research is needed to improve our understanding of performance drivers for an IT-worker system in NPD. Also, optimization research is needed to improve managerial decision making of the IT-worker system responsible for NPD. Empirical and optimization research is needed to better understand how market or technical uncertainty impacts the management of an NPD oriented IT-worker system.

Lastly, future research is needed exploring the unique challenges of motivating and managing a highly skilled and autonomous workforce at the individual and team levels (Wu et al. 2014). In the context of pursuing a radical NPD project, Huckman and Staats (2011) suggest the formation of fluid teams, where each team consisting of highly competitive individuals, bids to outwork other teams. They find that project performance improves if workforce efforts are smoothed over time. Taken together, Huckman and Staats (2011) and Wu et al. (2014) establish the need for a new set of operations principles and tools to manage the creative and autonomous workforce responsible for developing advances in science and technology.

### 4.2 Leveraging External Knowledge

In this section, we suggest research opportunities that deal with how a firm may leverage external knowledge to respond to the increasing complexity and distributed development of advances in science and technology.

#### 4.2.1 Alliances in a Supply Network

The empirical results in Bellamy et al. (2014) indicate that absorptive capacity (Section 2.1) plays a key role in enabling a firm to benefit from advances in science and technology via the interconnectedness in its supply network. However, Ahuja’s (2000) longitudinal study suggests that, under certain conditions, network interconnectedness may directly impact various measures of firm performance. Clearly, future research is needed to better understand the conditions that enable a firm to benefit from access to knowledge in its supply network.

Hora and Dutta (2013) empirically demonstrate that, to successfully commercialize advances in science and technology, a manager must consider the depth and scope of its alliance network. In addition, research opportunities exist in order to examine when firms should form alliances and at what future time the alliance goals should be met. These timing decisions are likely to be particularly important in industries such as the life sciences because the inherent scientific and technical uncertainty often leads to extensive delays for successful commercialization (Bhaskaran and Krishnan 2009). Furthermore, since substantial costs are incurred to coordinate, control, and sustain alliance relationships, future research is needed to unravel how such relationships should be managed to best facilitate improvements in a firm’s process capabilities.

#### 4.2.2 Alliances with Competitors

Research opportunities exist on the practical tradeoffs that occur when a firm forms an alliance with a competitor to develop advances in science and technology. First and foremost, future research is needed to improve our understanding of how to enhance the benefits and how to reduce the costs and risks of obtaining external knowledge from a competitor. Second, future research can provide a deeper understanding of how to pursue coopetition to develop derivative or radical NPD projects in different industries and in different competitive environments. Third,
4.2.3 Acquiring Knowledge from a Non-Competing Firm

Erat and Krishnan (2011) consider a buyer that relies on non-competing external sources of knowledge (suppliers) to develop new products, services, and business models. They find that, beyond considering the price charged by the supplier, the buyer must carefully specify the nature of the knowledge to be acquired. This suggests two important opportunities for future research. First, a deeper understanding is needed to identify the attributes and to quantify the scope of knowledge required by a buyer. Second, future research can explore how a buyer quantifies the levels of knowledge of potential suppliers to facilitate its supplier selection decision.

In ongoing research, Rahmani and Ramachandran (2015) consider how the structure of incentives set by a buyer impacts the highly skilled workforce employed by a non-competing external supplier to conduct specialized searches for advances in science and technology. A buyer could either provide the supplier with a well-defined deliverable or retain the flexibility to request a better solution. Intuitively, retaining flexibility may reduce the buyer’s risk of setting the deliverable too low. Interestingly, preliminary results suggest that the flexible incentive structure may drive the supplier to procrastinate, and thereby negatively impact the quality and timing of the buyer’s deliverable. In our view, this research exemplifies the emerging literature that seeks a better understanding of operations principles for the “production of knowledge output.”

Lastly, we note that Erat and Krishnan (2011), Lee et al. (2015), and Rahmani and Ramachandran (2015) introduce optimization models that consider how a manager should make decisions to maximize profit or to minimize cost. Given the nature of advances in science and technology, future research is needed that empirically defines and measures the multi-dimensional facets of knowledge; how knowledge is developed, transferred, and absorbed; and how knowledge is both a revenue and a cost driver. Lastly, experimental research is needed to provide deeper insights on the behavioral conditions under which all of the optimization models discussed in this chapter are most salient or simply do not apply.

5 Implications for Practitioners

Important implications for practicing managers are described throughout the chapter. In this section, we refer back to some of those insights and indicate the sub-section where the full discussion appears.

The chapter begins with industry examples to demonstrate the importance of the following:

- Process capabilities on firm performance in both manufacturing and service industries (including machine tools, distribution systems, and information technology (IT)) (Section 1.2).
- Advances in science and technology to improve process capabilities (Section 1.3).
Integrating product and process development to create new or to improve existing products, services, or business models (Section 1.1).

Comparing the benefits of building new process capabilities (new manufacturing facility or IT system) versus improving those that already exist (facility change or IT upgrade) (Section 1.4).

We explore how internal knowledge resources are used to generate advances in science and technology that lead to the successful introduction of new products, services, and business models and improvements in those that already exist. Insights to managerial practice include the following:

- Through a detailed discussion of the development of the Prius, we explore how Toyota leveraged its high level of process design knowledge and compensated for its low level of product design knowledge at the outset of the project (Section 2.1).
- We show how the frequently observed delays and cost overruns of radical new product development (NPD) projects may be the result of inappropriate incentives for the workforce (Section 2.2).
- We consider two NPD portfolio funding mechanisms found in practice and analyze their impact on (i) the investment in a radical project versus derivative projects, and (ii) the firm’s long-term performance in highly dynamic markets (Section 2.2).
- We describe the potential risks encountered when a manager relies heavily on upgrading IT to improve the performance of the IT-worker system responsible for NPD (Section 2.3).

Industry examples are given demonstrating how a firm leverages external knowledge about advances in science and technology to innovate process capabilities. Implications to managerial practice are explored in relation to three sources of external knowledge.

First, the competitive advantage gleaned from knowledge in a firm’s external supply network is enhanced if: IT is used as an enabler; employees are assigned explicit responsibility for KT; deep and long-term relationships in the supply network are nurtured; and careful consideration is given to the depth and scope of knowledge needed (Section 3.1).

Second, we consider a situation where competing firms form an alliance. Interestingly, the benefits realized when knowledge is obtained from an alliance with a competitor may be larger if the two firms have related knowledge. Also, the nature of the alliance may differ in response to market versus technical uncertainty (Section 3.2).

Third, a buyer always benefits from more absorptive capacity (e.g., from a greater ability to understand and apply outsourced knowledge from an external non-competing supplier); but the supplier derives benefits only under certain conditions. A buyer has more absorptive capacity if: (i) its workforce has the skills needed to understand and apply the knowledge outsourced from the supplier; (ii) its workforce has the necessary technical support (IT); (iii) incentives exist to limit the “not invented here syndrome” among its workforce; and (iv) trust exists between its workforce and the supplier (Section 3.3).

6 Conclusion

This chapter establishes that a firm’s process capabilities play a critical role in the successful creation of new products, services, and business models, and the improvement of those that already exist. We describe how process capabilities enable a firm to generate revenue and reduce costs by determining its product portfolio, time-to-market, quality of output, and volume of output.
We explore how a firm leverages both internal and external knowledge resources to generate advances in science and technology that lead to innovations in process capabilities. Lastly, we suggest research opportunities and highlight important implications for managerial practice.

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