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Putting manufacturing on the offensive

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Abstract: The path for elevating the role of manufacturing in the company strategy in the last few decades has been rather clear: Improve the basic production capabilities—typically quality, reliability, lead times, and cost efficiency of production processes. Leading Japanese companies, like Toyota, showed the way. But as many have heeded the advice and followed suit, this approach has become essentially a defensive strategy; you must do it not to fall behind. Has manufacturing lost its potential to create capabilities on which a company's strategy can rest? Our answer is absolutely not. In fact, unlike before, manufacturing has multiple paths for creating a competitive advantage and these paths require development of new and often nontraditional capabilities. We identify five sets of new capabilities, and since it is hard to excel in all of them, we provide a framework for choosing the right mix depending on the company's business strategy. The framework focuses on the implications of two recent trends: increasing information density embedded in products and increasing connectedness of manufacturing processes. We suggest specific mixes of the five groups of capabilities that can support and accelerate a company's strategy to exploit these trends. We use examples from three multinationals to illustrate the process. These new opportunities change the traditional role of manufacturing executives. Their focus will need to shift exceedingly to collaborating and interfacing with colleagues in other functions as well as managing relationships beyond the boundaries of the company.

Keywords: connectedness of manufacturing processes, information density of products, manufacturing strategy, supply chain capabilities

1 INTRODUCTION

In their seminal paper, *Competing through Manufacturing*, Hayes and Wheelwright (**1985**) introduced a four-stage model for gauging the role of manufacturing in the competitive strategy of companies. At the lowest stage (Stage 1), what they called "internally neutral," manufacturing was actually a weakness, and at the highest stage (Stage 4), "externally supportive," it was the leading competitive strength. It was a period when the world was discovering the Japanese manufacturing practices and witnessing how manufacturing could be on the offensive and create a formidable source of competitive advantage (Hayes, **1981**). The most celebrated example was of course Toyota. Deploying its famous Toyota Production System—the genesis of the lean program—Toyota was conquering world markets primarily through its superior manufacturing capabilities. Its production system surpassed rivals in quality, reliability, flexibility, dependability, and ultimately cost efficiency (Ferdows & De Meyer, **1990**; Giffi et al., **1990**; Ohno, **1988**; Womack et al., **1991**), giving the company a commanding lead over competition.

For the ensuing decades, Toyota's model became the de facto guide for upgrading the strategic role of manufacturing. Heeding the advice, many large manufacturers have deployed a version of a lean program and improved their production capabilities. As a result, developing superiority in basic production capabilities has essentially turned into a *defensive* strategy for manufacturing — "externally neutral" (Stage 2) in Hayes and Wheelwright's framework. Nowadays, it is hard to find cases where superiority in the basic production capabilities alone has been sufficient to push the strategic role of manufacturing to Stage 4. In fact, reacting to the recent

supply disruptions, some experts are questioning whether some companies have gone too far in that direction (e.g., pushed just-in-time excessively) and made their supply chains too fragile and vulnerable to disruptions (The Economist, **2020**).

Has manufacturing lost its potential to create capabilities on which a company's strategy can rest? We argue that manufacturing can still upgrade its strategic role but must develop new capabilities in areas beyond the traditional ones. Unlike before, there is no single path for this journey. The combination of new technologies, new business challenges, and new business models is requiring development of different mixes of defensive and offensive capabilities—that is, different paths—for upgrading the strategic role of manufacturing. These paths depend on the company's strategy and the maturity and strength of its manufacturing capabilities.

We describe these paths in this paper. Our focus is on how to choose the mix of capabilities, both new ones and existing ones that need to be deepened, to support or drive specific business strategies. We then propose a framework to guide this choice—that is, we identify different paths for developing the appropriate mix of capabilities for upgrading the role of manufacturing under different business strategies. We use examples from well-known companies to illustrate the process in practice and we conclude by speculating what the journey implies for the role of the senior managers in charge of manufacturing.

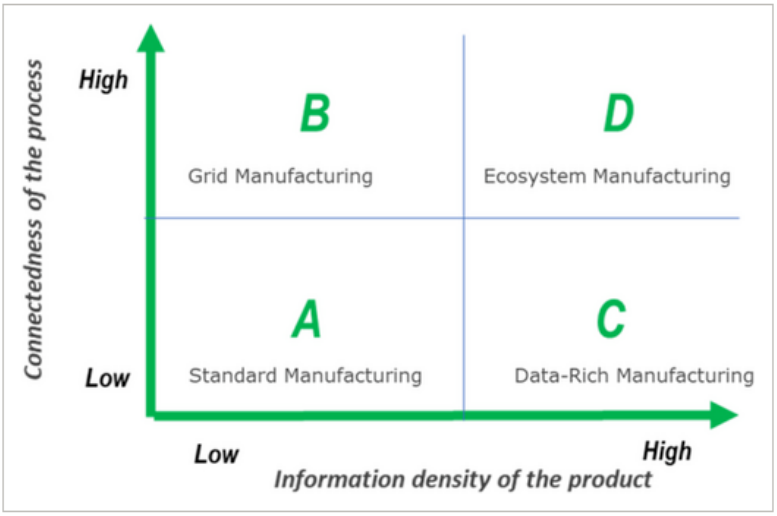
2 MULTIPLE PATHS FOR UPGRADING THE STRATEGIC ROLE OF MANUFACTURING

All manufacturers must cope with several new and growing challenges: improving sustainability of their products and processes, deploying new technologies rapidly, and managing disruptions—to name a few. But would a laser focus on any single one of them allow manufacturing to create a competitive advantage? We believe that it would be difficult. These capabilities are essentially *defensive*; they ensure that the company will not get into trouble. Moreover, since most manufacturers are upgrading their capabilities to respond to these challenges, it will be difficult to stand out.

A more robust approach, we propose, is for manufacturing to develop a distinct *mix of capabilities* that not only address these growing challenges, but also help the company go *on the offensive* in exploiting new business opportunities. Cataloguing all the possible capabilities is of course impossible but examining two recent trends can show how manufacturing can upgrade its strategic role.

The two recent trends are (1) *increasing information density of products* and (2) *increasing connectedness of manufacturing processes*. They are not the only trends that need attention, but we propose that they are among the most important developments that are creating new opportunities for upgrading the strategic role of manufacturing (see Figure **1**).

FIGURE 1: Possible directions for manufacturing



The two dimensions are continuous variables, but we have grouped the manufacturers into four quadrants to simplify the discussion. The measures on both axes are relative ones (compared to the average in the industry or competition) and can change over time. We define the attributes of manufacturers in each quadrant in more detail later, but a quick definition is as follows.

Most traditional manufacturers operate in Quadrant A—making and selling a component or product often in standalone factories or "isolated plants" (Vereecke et al., **2006**). While there will always be a need for such *standard manufacturing*, many manufacturers are moving toward the other quadrants.

Those that have moved toward Quadrant B, *grid manufacturing*, run their manufacturing as a network in the sense that their factories are tightly coupled with each other, with other functions, even with different producers and stages of production (Zhang et al., **2020**). For example, the output or by-product of one factory is input to another, exothermic processes in one factory are coupled with endothermic processes in another. Or they have established close linkages for frequent communications between their factories and other functions such as engineering, R&D, or distribution. Increasingly, physical proximity is not a prerequisite for being able to operate in this quadrant.

The companies that have moved toward Quadrant C, *data-rich manufacturing*, run their factories relying heavily on data collected from their customers and supply chains. Manufacturing in these companies has strong links with the users of the product and is an active participant in providing customized solutions for the clients (Porter & Heppelman, **2015**).

Those in Quadrant D, *ecosystem manufacturing*, have combined the capabilities of Quadrants B and C. All manufacturers operate in an ecosystem of suppliers, customers, logistics providers, and technical, legal, financial, and other service providers (De Meyer & Williamson, **2020**), but the manufacturers in this quadrant have established close links with many of them as well as with the end users of their products. They have an important role in managing the relationships with the ecosystem partners in the design, production, and distribution of products and in expanding the services they provide for their final customers and end users.

Increasing information density of products

Products are carrying increasingly more information (Porter & Heppelmann, **2014**). This trend has been very visible in some industries, such as food. The food industry has continued to add more information to its products—the list of ingredients, their nutritional values, "sell by" dates, and increasingly country or region of origin, conditions of the cold chain that transported the product, and even guidance for cooking, preservation, and disposal of the packaging. This trend can also be seen in other industries, such as medical devices, autonomous cars, communication appliances, and apparel. Collecting, analyzing, exploiting, and providing these multitude of data require new capabilities to be developed in production and supply systems.

Increasing information density of products raises at least four categories of questions for manufacturers:

1. How should the information accompany the product to the customer? What is the best way to provide the information that helps the customers optimize the use of the product in their production processes or consumption?
2. What is the role for manufacturing related to the information *collected during the consumption of products by customers?* Internet of things, digital twins, repairs, and field service, to name a few, are allowing manufacturers to collect direct data about the usage, tear and wear, even end-of-life of their products. How can manufacturing facilitate using these vital data in the design of the product and its production processes? This will be particularly important if the company is servitizing its offering and shifting from selling "products" to selling "solutions" or "experience," as explained later. For example, using the rich data collected during the use of their products, Apple and Caterpillar are offering proactive services that enhance their competitive position.
3. How is manufacturing impacted when the information that flows with the product is combined with information coming from customers, suppliers, service providers, regulators, intermediators, and other sources in its ecosystem? For example, how should the information about the handling of products in the

supply chain (e.g., how cold was the "cold chain" for a pack of pharmaceuticals) affect management of manufacturing and the supply chain? Or how does the information about how ethical is the supply chain (e.g., did any supplier or their subcontractors use child labor) alter any practices by manufacturers?

4. Physical products wear out with utilization and are typically discarded after their useful lives. Data, information, and knowledge do not wear out; on the contrary, they are enriched by continued use. Manufacturing is usually not involved in collecting or analyzing such data, but given the explosive growth of sensors, among other factors, there is a possibility to change its role. How can manufacturing effectively gather and exploit rich data throughout the full life cycle of the products it produces? For example, jet engines wear out as they accumulate flight hours, but the knowledge on how they function is constantly enriched with the data they generate. It indicates when the engine needs maintenance, or highlights opportunities for improving the design of the product or the manufacturing process.

Connectedness of the process

The second axis in this framework captures the interconnectedness of the production processes. In some industries, like the chemical industry, linking different production processes is not new. Integrated chemical production facilities (often called "Verbund" in the German chemical industry, with the largest one in Ludwigshafen owned by BASF), where the by-product, often effluent, of one factory is raw material for another, are common (Ferdows & Carabetta, **2006**). Examples in other industries include industry parks—for example, Kalundborg in Denmark, Rantasalmi in Finland, Mipo Ulsan in South Korea—or Sainsbury's integrated energy production facility in the United Kingdom that uses packaging and food waste (The Guardian, **2010**). In many of these complexes, there is a symbiotic relationship between often independent manufacturers providing resources and services to each other (Bhattacharya et al., **2022**).

In recent years, linking the manufacturing processes of different entities is gaining momentum, even if the factories are not in physical proximity and have no common owner or control. This is due to several drivers, chief among them the increasing concern for sustainability of operations and increasing value creation by working together in loosely coupled networks or business ecosystems (De Meyer & Williamson, **2020**).

Moving along this dimension raises at least three categories of questions for the manufacturers:

1. How can manufacturing contribute to the reduction of the complexity and transaction costs that come with collaborating with multiple parties in the network? For example, what new lines of communications need to be established between their factories? Should the different organizations establish new performance measures that capture combined performances of the connected production systems?
2. What can manufacturing do to go beyond just working together to promote *learning* between the interconnected partners or members of the production ecosystem? How can the tacit knowledge in these exchanges of information be codified? An important advantage of an ecosystem is that it brings partners with very different and complementary capabilities together (Roth et al., **1994**). But it is often a challenge to stimulate joint learning and creation of common "ecosystem goods" that can benefit the entire ecosystem without disadvantaging individual participants (De Meyer & Williamson, **2020**).
3. Ecosystems need to set up a process that ensures each of its participants can capture its fair share of value when the network delivers the final product to customers. What should be the role for manufacturing in that process?

Combining the two dimensions

Standard manufacturing (Quadrant A), as mentioned, is the traditional space for many manufacturers. Staying in this quadrant may be fine for producers of bulk materials, standardized components, or commodity products. If a company plans to stay in this quadrant, the path for upgrading its manufacturing's strategic role is essentially still through improving the basic production capabilities—quality, reliability, flexibility, and cost efficiency.

As companies move toward the other quadrants, there are new ways for manufacturing to upgrade its strategic role. Moving toward grid manufacturing (Quadrant B) can reduce its environmental impact by exchanging by-products and services with others, improve traceability of what it produces, and create additional value through closer cooperation with others. Moving to data-rich manufacturing (Quadrant C) allows manufacturing to get

closer to customers, increase its ability to customize products, as well as increase the traceability and transparency of its supply chains. And moving to ecosystem manufacturing (Quadrant D) allows the company to adopt new business models and offer radically new solutions to its customers by providing products produced in collaboration with a network of companies or an elaborate business ecosystem. Consider the example of autonomous vehicles. Producing them requires close collaborations between automotive producers, software developers, map providers, sensor producers, and many others. These companies need to generate and share considerable data. Their manufacturing can create competitive advantage by building unique capabilities for doing that quickly and effectively. The advantage is not only for their own companies but also for the ecosystem.

3 BUILDING THE RIGHT CAPABILITIES

Different moves on this framework, therefore, require development of different kinds of offensive capabilities in manufacturing. We suggest the most critical ones can be grouped into five broad categories shown in Table **1**. Some of the capabilities are not new but need to be deepened. In the next sections, we describe these capabilities and illustrate how they are being developed in three companies that are making different moves on this framework. We show how they are using their manufacturing to create a strategic advantage.

TABLE 1. Capabilities for new paths for upgrading the strategic role of manufacturing

New paths for upgrading manufacturing's role: Choosing the right mix of five categories of capabilities
1. "Expanded View" Looking beyond traditional functional walls of manufacturing
2. "New Technologies" Deploying new process and digital technologies quickly
3. "Products-to-Solutions" Developing new capabilities to support, help, or even lead the shift from providing mere "products" to providing "solutions" and enhancing the consumer experience
4. "Intra-company Network" Leveraging the intracompany network, shifting away from standalone operations
5. "Ecosystems" Working effectively in intercompany networks and ecosystems

Looking beyond traditional functional walls of manufacturing

Exchange of information and collaboration with other functions in the company and partners in the supply chain have always been important for manufacturing. But their importance increases substantially with more information density of products and interconnectedness of processes. Factories need to integrate better in their immediate surroundings and connect to larger numbers of their stakeholders to reduce potential adverse environmental, social, and regulatory effects. Final assembly plants may need to be located close to consumption to be in sync with the customers and to enhance responsiveness and reduce transportation. Urban factories, integrated in residential areas, may offer clear advantages in some cases by reducing commuting, distribution costs, and fulfilment lead times (Bhattacharya et al., **2022**). Closely working with nearby partners may enhance the robustness and responsiveness of supply chains.

As manufacturing reaches out to external partners, it must develop new skills that are different from managing a vertically integrated supply chain (De Meyer & Williamson, **2020**; Demeester et al., **2014**). It may, for example, have to learn how to reduce transaction costs and build trust with its partners (perhaps through new types of performance-oriented contracts), codify tacit process knowledge, improve interfaces, perhaps even police bad behavior by partners.

Deploying new process and digital technologies quickly

Recent technologies are radically changing traditional manufacturing (Boute & Van Mieghem, **2021**; Olsen & Tomlin, **2020**). Data captured from the vast increases in the use of sensors in manufacturing and supply chain are increasingly fed directly into production processes, connecting equipment and operators seamlessly; virtual twins and augmented reality are helping simulation of production processes and accelerating generation and acquisition of new knowledge; additive manufacturing, though still nascent, promises to grow rapidly especially in certain applications and change their production processes fundamentally.

Most large manufacturers have already developed the capability to deploy such technologies. But all signs suggest that the pressure is mounting, and all manufacturers must substantially improve the speed and agility with which they implement these new technologies, particularly to enable them to enhance their capability to look beyond the traditional manufacturing—to other functions inside the company, their upstream and downstream supply chains, and generally different members of their ecosystem.

But to expand the view of manufacturing, executives would need to make that a priority when deploying these technologies. To connect seamlessly and efficiently, the architecture of their chosen process technologies would need to be more open than usual to internal or external partners, which raises a challenge in justifying the investment in them. Traditional investment in new manufacturing and supply chain technologies have been justified by improved cost efficiency, reliability, flexibility, and safety in the factory itself. However, much of the expected gains from these new technologies are often outside the four walls of the factory—for example, in increasing reliability of supplies, reducing fulfilment lead times, mitigating adverse effects of disruptions in the supply chain, or improving customer service. Justifying an investment in "manufacturing," when the benefits are mostly realized outside the factory, is a formidable challenge in many companies.

Developing new capabilities to support, help, or even lead the shift from providing mere "products" to providing "solutions" and enhancing the consumer experience

Aided by fast moving advances in digital technologies (Lee, **2021**), many consumers are shifting from buying the product to buying the experience of using the product. Instead of buying light bulbs, they want a well-lit space; instead of a car, they want a comfortable and safe transport. Business customers, too, as the literature on servitization of manufacturing makes clear, are asking the same—*solutions* not just products. Instead of buying packaging equipment, producers want the services of running, monitoring, managing, and optimizing the packaging system; instead of buying tires for their fleets, fleet owners want to buy miles or kilometers of transport, and leave it to the tire manufacturers to optimize the production and maintenance of the tires over their life cycle.

The concept of servitization is of course not new (Fritze et al., **2018**; Neely, **2008**). But in recent years there has been a rapid increase in the service content also beyond B2B, with profound implications for manufacturing. Despite being traditionally a non–customer-facing function, manufacturing must learn how to contribute to creating solutions for customers and enhancing their experiences.

Leveraging the intracompany network shifting away from standalone operations

Exploiting the company's own global manufacturing *network* to mitigate adverse effects of disruptions is not as simple as most people believe. Company's organizational structures, profit centers, key performance indicators for manufacturing managers, among other factors, are often obstacles. As the disruptions in supplies during the early 2020s revealed, these obstacles are becoming costly handicaps. A *network* of factories can cope with sudden changes in demands, disruptions in supplies, and other unforeseen events much better than the same set of factories when they are run independently. It also offers more opportunities for learning and knowledge transfer. However, for many manufacturers operating as a network is a challenge, especially when both products and production processes are complex and have high contents of proprietary know-how (Ferdows et al., **2016**). It often requires major changes in the management and architecture of the company's global production network, which is not a simple task. It requires revisiting a host of complex decisions related to offshoring, reshoring, near shoring, and outsourcing.

Working effectively in intercompany networks and ecosystems

Moving toward providing *solutions* and enhanced *experience* for customers would demand more collaborations with the ecosystem partners, not only in the daily operations but also to innovate and create new value for the customer (Hayes, **2008**). Learning how to do that would not only improve manufacturing operations but will also improve manufacturing's capability to mitigate disruptions. Partners in a business ecosystem can learn from each other and combine capabilities to develop new value for the end customer. An ecosystem can enlarge the value proposition by mobilizing resources to solve problems and remove obstacles that are beyond the capability of any of its members alone (see, e.g., Ferdows et al, **2022**; Pich et al., **2002**).

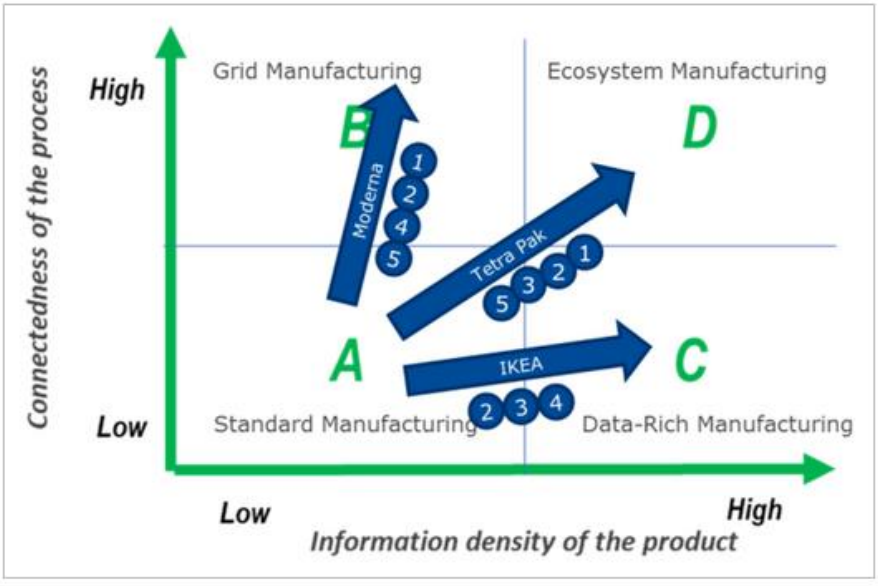
4 CHOOSING THE PATH

While manufacturers cannot ignore development of any of these capabilities, trying to excel in all of them would spread their resources and attention too thin, reducing their chances of developing distinctive superiority in any one of them. While some of these capabilities partly support and reinforce each other, a company benefits from clarifying which of these capabilities must be developed or deepened further to turn its manufacturing into a competitive weapon.

The framework in Figure 1 can help the process. To illustrate, we analyze recent moves in the positions of three large manufacturers on this framework: Moderna (a U.S. pharmaceutical and biotechnology company, headquartered in Cambridge, Massachusetts), IKEA (a Swedish multinational, world's largest retailer of furniture, and world's largest manufacturer of wood products, headquartered in Delft, The Netherlands), and Tetra Pak (a Swedish–Swiss multinational, world leader in food packaging, headquartered in Lund, Sweden, and Pully, Switzerland). In recent years, these three companies have embarked on upgrading the strategic role of their manufacturing and are moving from Quadrant A to other quadrants. Each is focusing on a somewhat different mix of the five capabilities. (See Figure 2, and for more details see the Appendix.)

- *Moving from standard to grid manufacturing (from Quadrant A to Quadrant B): Moderna*

FIGURE 2: Illustration of paths for upgrading strategic role of manufacturing at Moderna, IKEA, and Tetra Pak



In recent years, Moderna has been upgrading the strategic role of its manufacturing primarily through closer integration with other internal functions and its suppliers. In the process, its manufacturing's role in drug discovery and fast introduction market has expanded significantly (Iansiti et al., 2020). For example, the company recently built a greenfield factory in Norwood, Massachusetts, close to its headquarters, which also houses R&D, clinical production, and commercial production. This plant has made it easier for manufacturing to work closely

and exchange knowledge with others beyond its functional walls—that is, enhancing *Capability 4* (intracompany network) and *Capability 1* (expanded view). Moderna is also strengthening *Capability 5* (ecosystem) through partnership with organizations in its ecosystem, combining their resources to expedite production and distribution of new drugs. Finally, as a part of its vision of becoming a fully digitized company, Moderna has been upgrading *Capability 2* (new technologies) of its manufacturing by investing heavily in new process technologies and creating integrated, digitized, and automated systems in its plants worldwide. These capabilities have proven to be particularly effective in the rapid introduction of its Covid-19 vaccine.

- *Moving from standard to data-rich manufacturing (from Quadrant A to Quadrant C): IKEA*

The rapidly growing share of online sales has prompted fundamental changes in all of IKEA's operations, including its manufacturing (Ferdows & Olhager, 2020). Compared to store customers, online customers have a larger number of products to choose from (and possibility to customize them—e.g., in their favorite fabric color), they place smaller orders, they expect quicker delivery, and they return a larger portion of what they purchase. All of this creates new challenges for manufacturing. IKEA Industry (the manufacturing division of the IKEA Group) is meeting this challenge primarily by building up *Capability 2* (new technologies). Its investments in new technologies enable its factories to produce small batch sizes efficiently as well as gain more visibility into their downstream supply chains, that is, IKEA's distribution centers and stores around the world. IKEA has also focused on *Capability 4* (intracompany network) as it recently restructured the allocation of production of different products to its factories in its global production network. For example, it is removing products with volatile demands produced in small batches from factories that are assigned to produce large volumes. It is turning some of the factories in its production network to specialize in making small batches with short lead times. The goal is to respond to changes in demand more as a *network* than as standalone factories. IKEA has also invested in *Capability 3* (products-to-solutions), which has direct implications for its manufacturing. Customers can use IKEA's virtual reality app or visit one of the new "design stores" it is opening at city centers to simulate optimal designs for their homes. This is increasing the demand for customized products and requires development of new capabilities from IKEA Manufacturing.

- *Moving from standard to ecosystem manufacturing (from Quadrant A to Quadrant D): Tetra Pak*

This is an ambitious move. Tetra Pak, a world leader in food processing and packaging systems, has been moving from producing "products" to providing "end-to-end-solutions" in processing, packaging, and services for its customers and for their consumer (Markoff & Seifert, **2018**). Manufacturing at Tetra Pack has a significant role in making this strategy work and has been strengthening its capabilities in several areas. First, it is building direct connections to customers and consumers, strengthening *Capability 3* (products-to-solutions). It has created a "control tower" to gain visibility in its end-to-end supply chain. Using remote sensing, Tetra Pak can monitor quality and output of its machines on the customer factory floor, and initiate maintenance and adjustments for productivity improvement to be done either by its customer or Tetra Pak itself. It can even build digital twins of customers' production processes and help customers improve further.

Manufacturing at Tetra Pak has also strengthened *Capability 5* (ecosystems) and is working more effectively in its wider ecosystem of material suppliers, technical experts, app developers, customers, end users, and others to improve its ability to provide solutions to customer problems. Investing in the smart and connected factory—*Capability 2* (new technologies)—through the deployment of new technologies in manufacturing, is at the core of Tetra Pak's digital transformation strategy. Tetra Pak's longstanding world class manufacturing capability helps the company to move beyond the factory walls, protecting people and food, that is, *Capability 1* (expanded view).

Upgrading manufacturing's strategic role can of course be done by strengthening the position within a quadrant. Novo Nordisk is an example. Novo Nordisk—a Danish multinational pharmaceutical company headquartered in Bagsværd, Denmark—is deepening its capabilities to strengthen its grid manufacturing position (within Quadrant B). The Novo Nordisk plant in Kalundborg, Denmark, benefits from its location in the Kalundborg ecoindustrial park, where symbiosis with other factories provides easy access to energy, water, and other resources. Novo Nordisk shows its commitment to *Capability 1* (expanded view) by emphasizing the plant's connection to its environment, making it not only a place to work, but also a place to live and engage with the local community.

Manufacturing at Novo Nordisk also plays an important role in the production of the next-generation products that offer individualized, data-driven disease management and self-care to the patients. Through developing partnerships and collaborations with the members of its ecosystem, manufacturing is building *Capability 3* (products-to-solutions), and *Capability 5* (ecosystems). Furthermore, while the Kalundborg plant is already producing about half of the world's insulin, the company plans to expand it further and support other facilities worldwide—that is, strengthen its *Capability 4* (intracompany network).

As suggested by these illustrative cases, in general, if the strategy of the company requires moving up in this framework, the emphasis should be on developing *Capability 1* (expanded view), *Capability 4* (intracompany network), and *Capability 5* (ecosystems). If the move is to the right, the emphasis should be on *Capability 2* (new technologies) and *Capability 3* (products-to-solutions). Moving up diagonally is the boldest move, requiring, most importantly, manufacturing to look beyond its traditional walls (*Capability 1*), and deploy new technologies (*Capability 2*), lead the shift to provide solutions (*Capability 3)* as well as collaborate closely in the ecosystem (*Capability 5*). It is both a big challenge and opportunity for manufacturers. But it can provide the greatest competitive advantage as it would be difficult to match.

5 IMPLICATIONS FOR THE MANUFACTURING EXECUTIVE

Thirty years ago, De Meyer and Wittenberg-Cox (**1992**) showed that manufacturing executives were mostly internally focused: spending 30% of their time on supervision and training, and 43% on internal communication, almost equally spread over communication with plant staff, communication with colleagues from other departments (sales and marketing, R&D), and communication with senior, upper management. Dealing with the community took only 5% of their time.

Times have changed. Going beyond the traditional ways of upgrading the strategic role of manufacturing requires a substantial shift in the roles and responsibilities of the executives who manage production and operations. Building direct links to customers and providing "solutions" to them rather than mere "products," working in partnership with members of their ecosystems, deploying new technologies that affect operations outside manufacturing, improving sustainability of their end-to-end supply chains, all require new roles and leadership qualities.

This is unchartered territory. Take, for example, the leadership required for the development of *Capability 2* (new technologies), in which the role of manufacturing executives goes beyond ensuring allocation of sufficient resources or finding a good technology provider. The business case for investments in new technologies often include elements that are not easily quantifiable and need new ways to justify. The manufacturing executives must therefore hone their skills in convincing the upper management to provide the resources (funds and people) needed to upgrade the strategic role of manufacturing. They also need to hone their skills in building close lateral internal interfaces. As a manufacturing executive at Moderna explained "You cannot blindly translate manual processes into digital processes. The processes, once set, must be redesigned to fit in a digital environment. It is important to do this exercise holistically rather than in silos, or else optimization will only happen in individual pieces" (Iansiti et al., **2020**, p. 6).

In short, as manufacturing's strategic role shifts from defensive to offensive, manufacturing executives will find that they need to spend more time interacting with the top level of the organization (Demeester et al., **2014**). That may require a change of routines for some of them. Whereas highly accomplished manufacturing executives are skilled in improving quality, reliability, flexibility, dependability, and ultimately cost efficiency of their production systems, building the new capabilities listed in Table **1** requires a new set of skills, most important of which are the following:

First, they need to learn more about managing significantly increased interfaces with those outside manufacturing. They include their partners in the end-to-end supply chain, partners in their business ecosystem and the community where they are located. They need to become excellent communicators who can "speak the language" of all stakeholders.

Second, they need to expand their knowledge of recent technologies—how big data, virtual reality, machine learning, and artificial intelligence (AI) are affecting management of manufacturing. They must learn how to exploit the rich data collected from customers as they use the product to create additional value for the customer. They must play an active role in finding new ways to provide "solutions" for their customers.

Third, they must become more knowledgeable about their own company's production network and the supply ecosystem—including several layers up and down their supply chains (Agrawal et al., **2014**). Since working with partners in the network and ecosystem often cannot be done through command and control, manufacturing executives will need to improve their soft power skills, like picking up weak signals from partners, listen carefully, and hone their ability to convince others. All this would be in sharp contrast to the stereotype image of the "take-charge," "fire-fighter" production manager.

6 LOOKING FORWARD

Can manufacturing still play a decisive role in shaping and improving a company's competitive position? Our answer is "of course," but going on the offensive in shaping and supporting the company's strategy will require a new approach, different from what we have essentially pursued in the last 30 years. Keeping the operations lean is still important, but focusing only on that is not likely to lift manufacturing's role in the business strategy in most companies.

We suggest that manufacturing stands a better chance for creating strategic advantage by building new capabilities that enable the company benefit from two current trends: (1) increasing information density of the products and (2) tighter connection between different manufacturing processes. We posit that if manufacturing can build the right portfolio of capabilities for moving further along these two dimensions, it will upgrade its strategic role. More empirical research is needed to refine the details of the broad capabilities we have identified and to determine the appropriate mixes of these capabilities that support specific business strategies. The framework we propose in this paper, we suggest, is a useful first step.

A direct result of being able, once again, to elevate the strategic role of manufacturing is enhancing the role of the manufacturing executives. It will make this position more attractive to young and ambitious managers. To be successful, they will need to master new skills on top of technical knowledge and command of concepts and models of managing manufacturing and supply chains. They will also need to develop deep understanding of digitization and new technologies as well as focus on collaborating and proactively interfacing with colleagues in other functions and managing relationships with entities beyond the boundaries of the company. These requirements offer tremendous opportunities for renewing and updating how we educate our students and prepare future manufacturing executives.

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APPENDIX: DEVELOPING MANUFACTURING CAPABILITIES AT MODERNA, IKEA, TETRA PAK, AND NOVO NORDISK[1]

		Capability
Moderna	1.	The Norwood (Massachusetts, USA) factory houses three independent units (preclinical R&D, personalized cancer vaccine, and the clinical area) that are strongly connected digitally to stimulate transfer of learning from one to the other.
	2.	Fully digitized and automated factory: using robotics, analytics, and AI; machines connected to a fully digital system.
	4.	Investment in a state-of-the-art, greenfield factory (in Norwood, close to headquarters; opened in 2018; expansion plans announced in May 2021) giving more control over the manufacturing process and allowing to produce drugs faster than with the previous globally dispersed supply chain, while saving manufacturing costs.
	5.	Partnerships for gaining scale in manufacturing with Lonza, Sanofi, Samsung Biologics, and Catalent.
IKEA	2.	Manufacturing System of the Future: project launched in 2017, adopting several Industry 4.0 technologies for IKEA Industry.
	3.	Collaborating with a major supplier of simulation software that enables customers to simulate their ideal kitchen customized to the space available at home.
	4.	Reallocation of products to factories, distinguishing between "High Runner" (for high volumes, low variety) and "Flex Runner" (for low volumes, high variety) factories
Tetra Pak	1.	Tetra Pak's World Class Manufacturing program contributes to its brand promise—PROTECTS WHAT'S GOOD™, which includes the promise to protect food and people.
	2.	Creating the smart, connected factory, through sensors, AGVs, MES & APS, to monitor every step in the manufacture of the packaging materials. Supply chain control tower to create visibility of inventories across the supply chain and finetune production planning.

[1] Note: Information about the four companies was taken from authors' observations and interviews, companies' websites, annual reports, and case studies:
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Additional details are available upon request from authors.

	3.	Connecting to the customer's production site through IoT, digital twins, machine learning, mobile applications, and augmented reality. Connecting with the consumer through QR code on the package, containing valuable information for the consumer & becoming a channel of interaction.
	5.	Working with suppliers to promote renewable materials, minimize emissions, and protect biodiversity and fresh water. Working with customers, providing them with the solutions to maximize production efficiency and minimize energy use, waste, and emissions. Hackathons and Design Sprints, involving employees, external experts, and end users.
Novo Nordisk	1.	Focus on the plant in its environment: A great place to live, close to nature, strongly engaged with the local community, a place for sporting and hiking, etc.
	3.	Focus on digital solutions to facilitate disease management and self-care and provide individualized, data-driven support to patients.
	4.	Upgrade and expansion of the plant in Kalundborg, Denmark, a cornerstone of Novo Nordisk's global production network, to create additional capacity for manufacturing the pharmaceuticals of the future.
	5.	Proactive collaboration with suppliers to embed circular thinking across the value chain. Collaborations and partnerships for developing digital therapeutic solutions offering individualized care to patients.