Business leaders who misjudge the location of production relative to the location of product and process development resources may adversely impact the company's long-term competitive position. We explore the link between production location decisions, the nature of the capabilities required to create a product, and the ability of a company to develop the next-generation technologies it may seek.

Location, Learning and Logistics

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Consider this scenario in which you want to develop a new capability: You want to learn to drive a car.

You're 16, sitting behind the wheel for the first time. You have spent your life watching Mom and Dad from the back seat. They explained it all to you. Now it's your turn. Start the car. Put one foot on the brake. Put it in "Drive." Go easy on the gas and—away you go! You're driving.

Now reframe the situation in a small but important way:

You're 16, sitting behind the wheel for the first time. You have spent your life watching Mom and Dad from the back seat. They explained it all to you. Now it's your turn. Start the car. Put one foot on the brake—and the other on the clutch. Move your right foot off the brake and onto the gas. Ease off the clutch and add a little gas. The car lurches forward and dies. Try again.

A few dozen more attempts at getting rolling and you can begin to think about shifting into second gear.

For most people, there are big differences in approach when it comes to learning to drive an automatic versus a manual transmission-equipped vehicle. Even though the objective is the same (get the car moving), differences in the specific nature of the task necessitate different ways of learning how to accomplish it. Most drivers require some trial-and-error to become proficient at operating in a manual mode. You can only get that by actually trying to drive the car.

Now imagine there is only one place to practice, and it is 11,000 miles away.

An observer might take this last bit of our example and assert that few would ever learn to drive a vehicle with a manual transmission. Under the best of circumstances, the geographic separation of the practice (capability development) location and actual driving (capability execution) location would dramatically lower the odds of the learning taking place.

Yet this is exactly the decision that many executives make when it comes to the development of important capabilities for their businesses—capabilities more crucial than mastering the nuances of the clutch pedal, and with broader implications. Decisions about how to locate development capacity versus execution (henceforth we will call it "production" capacity) can exert a strong influence on a company's future success.

This article explores the link between production location decisions, the nature of the capabilities required to create a product, and the ability of a company to develop the next-generation technologies it may seek. While the consequences vary by company, a common theme emerges: Leaders who misjudge the location of production relative to the location of product and process development resources may adversely impact the company's long-term competitive position.

Here we provide a framework to guide executives as they consider how best to position production capacity around the globe. The framework highlights important trade-offs in the pursuit of an optimal facility location that may ultimately influence company success. There is an opportunity to enhance the quality of location decisions by building on the classic determinants of capacity location—factors such as real estate costs and availability, taxes and incentives, logistical costs, and importantly, the availability of talent—with an appreciation for the profound impact such decisions can have on the ability of the company to develop future products.

Our framework considers three learning and logistical factors that contribute to an effective production location decision:

- Learning mode: The manner in which knowledge about the production process is transferred from R&D to the factory floor
- Market-to-plant ratio (MPR): The capacity of the market to support more than one production location
- Value density: The relationship between product value and the logistical costs of distribution.

Two case studies illustrate the framework in action. First, in the early 2000s, many firms in the optoelectronics industry moved production offshore to save costs, a decision that led to unexpected trade-offs with next-generation product development. Second, we consider the Spanish company Ingeteam Corporación S.A. Ingeteam is a producer of electric power conversion equipment, supplying its products to, among others, the wind power industry. The company adopted a hybrid location model that preserved its ability to develop high-quality products and enabled the firm to customize those products for the US market. Ingeteam demonstrated how multiple production locations can be designed to protect product development capabilities.

Location is influenced by how learning is transferred from R&D to production

The manner in which learning about how to produce something occurs should be a fundamental input to the decision about where to locate facilities,

particularly in relation to the research and development capabilities that are critical for next-generation versions of a product.

Research identifies two primary modes of learning related to the transfer of capabilities from the lab to the factory floor: learning-before-doing and learning-by-doing.

"Learning-before-doing"

Learning-before-doing can take place when a process is so richly described, so well understood, that development engineers can communicate a process and product design with precision.[1] In learning-before-doing, a receiver of knowledge about a process simply needs to understand what is being said and can act to accomplish the task. Production personnel can therefore execute without close interaction with designers. Because learning is completed before doing, manufacturing is able to move closer to regional markets—often separating development and production—in pursuit of more rapid response, improved production economics, and hopefully, competitive advantage.[2] Conversely, production can also move further away from markets in order to take advantage of savings in lower-cost geographies.

Successful execution of a learning-before-doing approach requires that critical variables of production are known. Processes and techniques must be well defined, relying on technology that is stable and clearly understood. This understanding allows for an accurate prediction of how the process will transfer to the factory floor, regardless of where the factory floor is located.

"Learning-by-doing "

In learning-by-doing, the executors of a task may need to test a variety of strategies and/or seek coaching prior to accomplishing their goal. Producers expect to improve over time and by trial and error. Critical variables may as yet be unidentified, making it difficult to predict how a process established in design will transfer to the factory floor.[3] Learning-by-doing contexts are those in which gaps between actual and potential or expected performance are likely to be revealed, and must be addressed, through cumulative production experience.[4]

When developers are directly involved with the factory floor they can identify clues and relevant information that may otherwise go unrecognized.[5] In the optoelectronics industry case that we will describe, engineers reported constant contact with the shop floor and "suited up" at least once daily to work with production personnel. This engagement allowed manufacturers to improve through a continual process of problem solving, which was triggered by the difference between actual performance and potential or expected performance as defined by the company.[6]

Firms facing learning-by-doing product and process transfers must consider the interdependencies between development and production as they think about the positioning of capacity. Separation of one from the other may sever important communication linkages and impede the ability to transfer knowledge across the company.

Ways to determine the number and location of production plants

The challenges presented by learning modes are amplified by decisions about the number of production facilities operated by the company. We will see that where multiple production facilities can be maintained, executives have greater latitude to manage the impact of learning modes and development. Many factors contribute to the choice of facility quantity, including available capital and management attention, but two simple metrics allow executives to generally assess the optimal number: market-to-plant ratio and value density.

Market-to-plant ratio

Market-to-plant ratio (MPR) offers insight into the economic viability of multiple production facilities. It is calculated as a ratio of global market demand for a product and the minimum efficient size for a production facility.[7] For example, if the market for a company's product is 1 million units and the minimum efficient plant size is 250,000 units, then the MPR is 4.

An MPR close to 1 indicates market demand is likely insufficient to support multiple production facilities. Companies competing in high technology and growth-oriented industries often face this constraint.[8] MPR tends to be higher in stable, mature markets, allowing companies in these markets to support production across multiple geographies.

Value density

Companies may choose to limit the number of production facilities they employ even in situations where MPR allows a greater number. A reason may be the value density of the products they sell.

Value density summarizes the relationship between a product's value and the logistical costs associated with its distribution. It is calculated as the ratio of these two measures. When a product is value dense, companies have an incentive to centralize manufacturing even when MPR does not make it necessary to do so.[9] Alternatively, low value-density products offer incentives to scatter productive capacity more widely. Here companies prefer to locate close to end demand so they can limit the logistical cost of delivery.

The role of value density in the production process is illustrated by the market for soft drinks. Despite the $18.3 billion US soft drink market commanding a high MPR, the production of the concentrated syrup from which the final drink is made tends to be focused in a small number of locations.[10] Final production of soda occurs at the widely scattered bottling locations to which this value-dense syrup is shipped. Once there, the syrup is combined with carbonated water and packaging—dramatically lowering its value density—and distributed to the final customer.

Many factors contribute to the choice of facility quantity, including available capital and management attention, but two simple metrics allow executives to generally assess the optimal number: market-to-plant ratio and value density.

Value density examples

- Many consumer electronic and other technology products are value dense. They are often of high value, yet also tend to be compact and relatively easy to ship and manage through distribution channels. Producers often centralize production in a few locations and ship globally as needed.
- Bulky or heavy products such as furniture, foam products, and many commodities are low value-density products. The logistical costs associated with distribution are often high relative to the cost of the product itself. Producers have the incentive to push production closer to the end consumer in order to save on these costs.

Framework for integrating facility quantity and learning mode

Researchers have found that a combined understanding of factors related to learning mode, MPR, and value density can inform the plant location decision in important ways.[11] Here we adapt their frameworks to help guide decisions as to how to position production capacity around the globe. Our framework allows us to situate a company or product line in one of three sectors based on attributes associated with learning mode, MPR, and value density. The framework can also be used to monitor the migration of the company or product line across the different sectors as market conditions change.

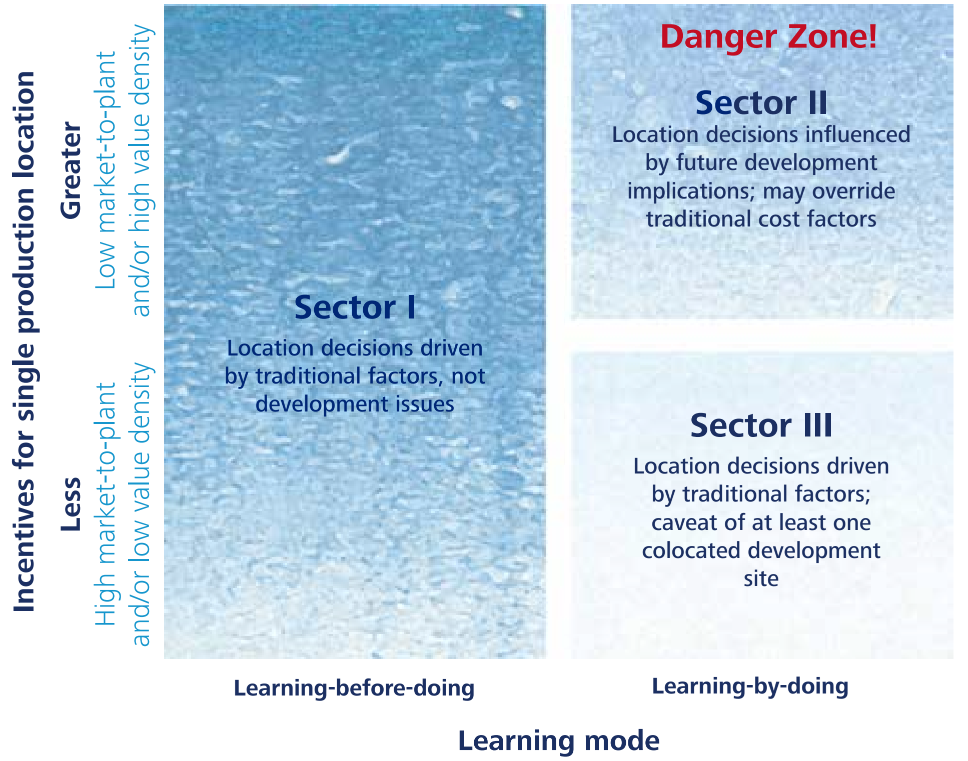
In proposing this version of the framework (figure 1) we note that, for the most part, the regular rules of location strategy apply. It is incumbent upon executives to account for traditional factors such as real estate costs and availability, taxes and incentives, logistical costs, and importantly, the availability of talent as they choose production locations. Yet there are important additional insights to consider as part of a location strategy.

Sector I corresponds to contexts in which learning-before-doing is the relevant learning mode for a company's production process. The well-understood attributes of the production process allow for a relatively easy separation of development and production. Increasingly ubiquitous electronic communication methods continue to accelerate the ability of companies to operate over extended distances, perhaps increasing the incentive to pursue lower-cost locations that exist closer to local pockets of demand.[12] Learning-before-doing, it turns out, can dramatically lower the risks of such decisions.

Sector II companies inhabit a danger zone in which learning-by-doing is required and the company is constrained to a single production location. Executives may feel the need to retain an engineering core in a highly skilled development site, yet ship production off to lower-cost locations in order to improve profitability. As we will see in the example of the optoelectronics industry, this decision can have a profound impact on the developmental trajectory of companies and markets.

Sector III companies face a different challenge. Here a high MPR and/or low value-density provide companies with the incentive and ability to geographically distribute production capacity. However, caution is still warranted, as learning-by-doing demands access for development engineers

Figure 1: Positioning capacity relative to plant quantity and production learning mode



to the factory floor. Production in such environments can grind to a halt without proper engineering support.[13] Sector III companies must understand their production processes at a depth that allows them to separate those critical aspects that demand learning-by-doing from those that can be segregated from development resources in pursuit of other objectives. In some cases, the demands of different production environments or stages may require the colocation of different kinds of development capabilities at different sites. This approach may yield hybrid location strategies that allow the company to push forward with its new product development objectives while simultaneously enjoying the benefits sought in traditional location decision-making processes. Failure to foster this understanding may result in retarded progress toward product development objectives. The case of Ingeteam will illustrate how one company managed this trade-off.

Application of the framework—Optoelectronics and wind turbine generators

Sector II framework and consequences: The optoelectronics industry

Optoelectronics provide an example of an industry confronting the Sector II danger zone of the framework. Recent research by Professor Erica Fuchs and her colleagues at Carnegie Mellon University demonstrates the challenges faced by firms in this industry as development needs are traded off with the incentive to locate production in low-cost geographies.[14]

Next-generation optoelectronics

Optoelectronic devices convert electronic signals to light, and vice versa. They are preferred to more traditional electronic devices for some applications because of their resistance to the electromagnetic interference that vexes designers of highly dense circuitry. They play a critical role in the telecommunications industry, as providers strive to offer their customers more bandwidth.

In addition to telecommunications, optoelectronics have the potential to revolutionize computing. As the power of microprocessors continues to rise, issues of information transfer between them continue to emerge. However, in computing, size matters a great deal more than it does in telecommunications. In 2000, then-current-generation optoelectronic devices were too big to make headway in the computing market. The key to market penetration was size-reducing integration. Standard optoelectronic devices incorporate six different components. As of 2010, manufacturers could only integrate two at a time on a single chip. The ability to integrate the remaining components (or even just a larger number), thus reducing the size of the device, remained a critical challenge for the industry.

In the early 2000s optoelectronics manufacturers faced intense competition. With the bursting of the technology and telecom bubble, optoelectronic component manufacturers had to make a critical choice as to whether to retain production at their domestic sites in developed economies such as the United States, Europe, and Japan, or to move manufacturing to the lower-cost developing countries of East Asia. In this case, the current-generation technology was sufficiently well understood to make such a move possible. The cost advantages were there for the taking. So compelling was the incentive that seven of the eight US-based optoelectronic component manufacturers studied by Fuchs and team chose to relocate manufacturing offshore.

The consequences for firms that moved production to lower-cost locations may not be obvious at first. However, industry analysis in light of our framework helps illustrate potential long-run effects and why the next-generation "integrated" technology for optoelectronics sits in Sector II of the framework:

- Producing next-generation integrated optoelectronic devices was a learn-by-doing activity. Reported yields for such devices ranged from 1 to 3 percent with the possibility of days passing between the creation of usable components.[15] Production, design, and test engineers reported having to go "down to the shop floor" multiple times per day in order to solve problems. The engineers highlighted the need for an "intimate" connection with the production process.
- The MPR ratio was close to 1. The market size for next-generation optoelectronics was approximately equal to the minimum efficient scale of a single production facility for each competitor, thus compelling them to choose a single facility.

- Optoelectronic devices are value dense, thereby increasing the incentive to consolidate production, even in the face of potentially growing markets.

Was offshoring production done at the expense of R&D?

Optoelectronics manufacturers that moved production offshore generated cost savings, but to the detriment of next-generation product development. The research of Fuchs et al. confirmed the cost advantage achievable by firms willing to move production offshore, even after accounting for reasonable learning curve effects and a dramatic improvement in process yields. Yet the researchers cautioned offshoring could have negative consequences on R&D.

If the optoelectronic component manufacturers move offshore and, because of a lack of short-term economic incentives to do so, cease to push forward research and development in optoelectronic integration, there could be dire implications for long-term technology development in IT globally.[16]

Related research on 28 US-based optoelectronic firms that made different decisions about offshoring linked those decisions to the subsequent ability to develop next-generation integrated devices.[17,18] Yang et al. made three observations about firms that offshored to developing geographies—in this case East Asia—in pursuit of cost advantages:

1. R&D activity on next-generation products substantially decreased, in particular when the most complicated, least understood chip fabrication sequences were moved offshore. Each additional year of offshoring corresponded to a 26 percent decrease in the development of next-generation integrated technologies.

2. Offshoring corresponded to a departure of the engineering talent responsible for next-generation development. In many cases, these engineers relocated to competing firms that were still engaged in next-generation development. In other cases, they left the field entirely, pursuing opportunities in other product domains. Regardless, the data suggests that not only could offshoring activity prevent or delay the development of products for new markets (such as optoelectronics in computing), it could also lead to an erosion of capability through loss of talent that forestalls future efforts at retrenchment.

3. Product development did not end with the choice to separate development and production, but it did undergo a material shift. Instead of focusing on the next generation of products (i.e., integrated devices), development efforts tended toward the improvement of the current-generation production process. Each additional year of offshoring corresponded to a 27 percent increase in these types of incremental improvements. While the researchers in this example did not assert a reason for this shift, we infer that the available talent pursued what was possible given their context and capabilities.

The US optoelectronics firms in the study that offshored production did generate sought-after cost savings, but the trade-off was their future competitiveness. The relative merits of this trade-off will be judged by history, but anticipating the effects of it is a matter for today's executives.

The Ingeteam location decision

Headquartered in Spain, Ingeteam specializes in the development of electrical equipment, motors, generators, and frequency converters. The company's Indar division produces generators for increasingly ubiquitous wind turbines. Indar generators, weighing approximately 7–10 tons each, are combined with a gearbox and other equipment in a 90-ton "nacelle" (cover housing) and hoisted 250–400 feet into the air where they are attached to a set of wind blades. Quality and reliability in this context are crucial. The gearbox accelerates rotation from a languid 20 RPM on the blade side of a wind turbine to the RPM2,000required to generate adequate power. A failure of the generator once it is "in the air" can cost up to $200,000 to fix.

In 2010 Ingeteam decided to increase penetration in the growing US market for wind power. Success in the United States required Ingeteam to gain a deep understanding of product component attributes and development needs specific to US compliance and regulations. The firm chose Milwaukee, Wisconsin, because of the area's manufacturing heritage and its proximity to other producers of power and control systems, potential suppliers, and customers. Ingeteam also valued a high-quality local workforce, solid local infrastructure, and the area's proximity to a major international airport.[19]

Sector III framework and consequences: The wind turbine industry

Ingeteam Corporación S.A. is an example of a company that has adapted its product development and production approach, balancing its need to meet market demand with an understanding of the types of learning required to succeed. The company fits within Sector III of our framework.

Ingeteam adopted a hybrid production model that gives it the benefit of local market access while maintaining developmental effectiveness. It achieved this by keeping approximately 95 percent of its core R&D capability at its central development site in Spain. Ingeteam's management chose to maintain production of rotors and stators (the core components of a generator) in Spain as well, because it felt more capable of achieving a combination of high quality, precision, and coordination with its development engineers. Their ability to do so is facilitated by the higher value-density of those components, relative to a fully assembled generator.

However, production in the United States requires its own kind of learning-by-doing. Ingeteam leaders cite cultural differences as a driver of the need to modify production operating procedures. Products also need to be modified to meet US code and tooling standards and to adapt to "the reality of the shop floor." According to Adolfo Rebollo, vice president of Indar Electric Machines:

This is an iterative process. There is lots of working together on the shop floor to make it happen. If we had to do it in Spain, we would have to bring a crew of Americans over just to figure it out. That is just not possible.[20]

Developing core system components required extensive interaction between engineers and production personnel—learning-by-doing—in Spain. Therefore production of those components remains in Spain. Adapting to local US conditions requires extensive interaction between engineers and production personnel—learning-by-doing—in the United States, where final assembly and adaptation now occur.

A balancing act

The choice of where to locate production can have a long-term impact on overall business success. Construction of new facilities is expensive and difficult to undo.

Traditional factors associated with location choice are important. Real estate costs and availability, talent, taxes and incentives, and logistical costs, to name a few, all impact the ability of a location to support the needs of a business. But so, too, does the impact of location choice on the ability of the company to evolve its product offerings.

Our framework offers executives another tool for location evaluation. They can position their companies in the framework and derive a better understanding of how to promote long-term business and product development success. They can also use the framework as a tool for evaluating capacity location strategies in light of ongoing market evolution. To use it, executives need to understand the important attributes of the markets they serve and the products they offer. They need to consider the mechanism by which knowledge about how to produce is transferred from the lab to the shop floor.

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The article was originally published on Deloitte Review Issue 13, a publication from Deloitte University Press

Note

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