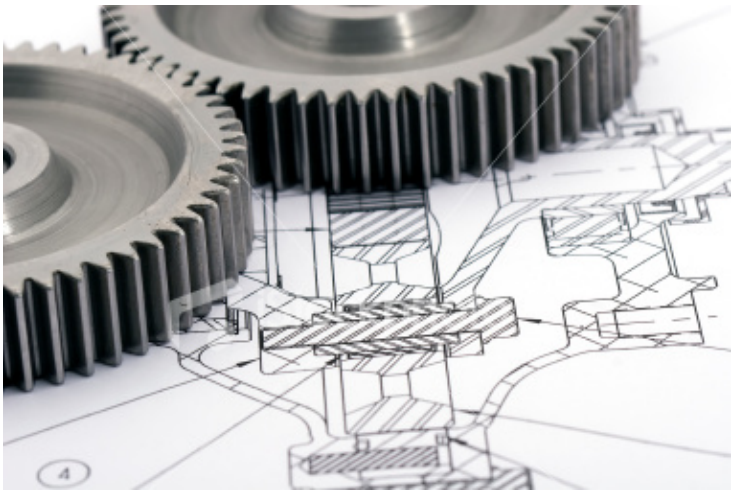

Incorporating risk and flexibility in manufacturing footprint decisions

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ABSTRACT

An increasing number of manufacturers are significantly reshaping their global manufacturing footprint, including radical increases in offshore production in low-cost countries and fundamentally rethinking their sourcing strategy. Too often, such footprint choices are made based primarily on their expected capacity and cost implications, without taking adequately into account the equally important aspects of risk, flexibility, and competitive positioning. As a result, companies leave value on the table from failing to make the right cost-risk-flexibility tradeoffs. This paper illustrates (with real-life case examples) some of the pitfalls companies have encountered, and outlines a more holistic approach that includes systematically identifying the key uncertainties and flexibility factors and quantifying their impact. This approach includes real options-related techniques incorporated into probabilistic risk modeling and footprint optimization.

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Introduction

Offshore sourcing, globalization, multinational mergers – an increasing number of industrial companies are facing both the necessity and the opportunity to reshape their global manufacturing footprint, redefining how much of each product, component, and part they or their suppliers will manufacture where. Sometimes this involves just output mix adjustments at existing production facilities. Increasingly, however, companies are also considering more radical options such as delocalization to low-cost countries or fundamentally redefining relationships with suppliers.

Any such major move involves significant uncertainty. There is uncertainty about externalities – the evolution of factor costs (for instance commodities, labor rates, and foreign exchange) as well as the evolution of price and demand. There is also uncertainty about internal execution – level of investment and time to execute major changes, as well as potential productivity and quality issues in a new environment. There is also uncertainty about the impact of unexpected events – geopolitical risks for instance – that may affect a changed footprint much differently than before. Companies generally realize these difficulties, and correctly mobilize considerable expertise and resources to prepare for these risks once a footprint decision is made, or to mitigate them as they occur. However, in our experience, decisionmakers rarely take these uncertainties into account sufficiently while exploring the footprint options and deciding which is the best route to follow.

We believe the best possible production footprint decisions result from comparing the alternatives simultaneously on all of the following dimensions:

1. **Capacity**. How much of what product can the footprint produce, and is that sufficient to meet growth expectations?
2. **Expected cost**. What is the total landed cost of production, given best estimates of all factor costs? What is the return on the expected investment needed to implement the changes to the footprint?
3. **Risk**. What are the key downside risk factors? How much do they impact the economics? This includes implementation, factor costs, as well as demand/revenues. To what extent and how can the risks be mitigated?
4. **Flexibility**. How does the footprint respond to changes in costs, prices, and demand from the currently predicted most likely level? This includes both flexibility to adjust production “within the four walls” of a single plant or product, but also, more importantly, the flexibility to reoptimize production across the whole footprint in response to change
5. **Competitive positioning**. How does the footprint compare to competitors’ footprints, and what benefits or limitations does that imply about the manufacturer’s positioning in the marketplace?

The first two dimensions are commonplace, but the last three are often just tacked on as an afterthought. That’s a shame, since especially the middle three often involve tradeoffs: lower cost but higher risk, or higher flexibility but also higher cost. Driving the decision off of expected cost and capacity alone can then leave significant value on the table, value which is hard to recover once a major footprint redefinition project is well under way. Techniques are available to help identify the types of risk and flexibility that are important early in the process, as well as to quantify the important tradeoffs to make the decision in a more informed way. These techniques constitute a pragmatic approach to quantifying the “real optionality” of a manufacturing footprint choice and including this optionality in the choice of the optimal footprint.

Understanding and quantifying footprint risk

By its very nature, risk involves dealing with the unknown. Altogether too often, decisionmakers are not sure how to deal with the unknown, so they just make a best guess, use that to drive the decision, and then (hopefully) do a bit of stress-testing on the back end to make sure that the results of being somewhat wrong are not too horrific. The problem is that making a footprint change – especially when it involves outsourcing or offshoring production – brings on new and unfamiliar risks and reshapes existing risks in ways which can be quite counterintuitive.

Beware of hidden exposures

One company was exploring building a major plant in Eastern Europe, which would among other things bring back in-house production of a crucial part, which was currently being sole-sourced from a Western European supplier. The company was correctly concerned about foreign exchange and labor cost risk, and also about plant build speed and quality issues since it did not have experience in this geography. However, on reflection it turned out that the key subsuppliers of the current sole source supplier of the part were based in the U.S. Thus changes in the value of the U.S. dollar would eventually percolate through the value chain and translate sooner or later into the cost of the part, even though the actual supplier was based in Europe[1]. Therefore the company was currently facing significant but hidden U.S. dollar Fx exposure of which it was not aware. It turned out that moving to in-house Eastern European production therefore actually reduced the overall Fx and labor cost risk. There were opportunities to mitigate some of the implementation risks by a JV-type arrangement, even though it turned out to not be cost effective.

This example also illustrates another point. Quite often, companies fail to go deep enough in understanding the risks of their suppliers in general, and underestimate sole source risks in particular. They tend then to underestimate the risks of a single source geographically located in a low-risk country relative to the risk diversification of adding a second source, albeit in a higher risk country. There are cost-risk tradeoffs with either solution which require a comprehensive analysis of risk drivers to the supplier and sub-supplier level to understand properly.

Probabilistic estimation of key risks

In the above case, the potential footprint shift ended up unexpectedly lowering overall risk. However, companies even more frequently underestimate the risk of a footprint shift. Consider a diversified heavy equipment manufacturer that currently has a footprint heavily based in developed, high-cost countries. It has a total landed unit cost of production (indexed) of 100. The manufacturer had developed a new footprint option involving a significant shift to low-cost countries, with an expected (most likely) total landed unit cost of 79. This 21% saving was based on an in-depth bottom up cost build, including final assembly, components, parts, and logistics. The question was, how risky was this 79 – could it be a lot higher in the case of bad luck, and what should be done about it.

As a consequence of doing the bottom up cost build, it was fairly easy for the footprint team to test the sensitivity to basic financial or economic risks (such as upside and downside Fx, labour rate, commodity price, and inflation scenarios) and compare their impact on the status quo (SQ) and new footprint. This was helpful, but left unanswered how likely these scenarios were and therefore how realistic and meaningful the differences were. However, by combining data on historical

[1] Pricing clauses in the contract would limit the impact in the immediate term, but the likelihood of forced contract renegotiation was high.

volatility with expert estimates and market currency futures, it was possible to construct a probabilistic model that calculated a 80% confidence band for the total landed cost based on these basic risks.

The results are shown in Exhibit 1. It is worth being very specific about what it means. While Fx, labour rates, inflation, and commodity prices are uncertain, if they behave as history, the futures markets, and experts believe, the total landed cost of the new footprint is 80% likely to be between 69 and 90, while the status quo footprint is 80% likely to be between 93 and 109. This assumes all other risks and uncertainties behave according to the base case – no unexpected supply chain meltdowns, South East Asian mega-earth quakes, or extreme but unexpected currency devaluations. With this in mind, it is clear that while the risks of the new footprint are proportionately larger, the cost savings is such that it appears clearly worth it. What is more, the quantitative analysis leading to this result highlights exactly how the risks have shifted. Exhibit 2 shows a deep dive on labor cost, indicating how over half the risk would shift to developing countries in the new footprint.

Exhibit 1. Footprint risk comparison

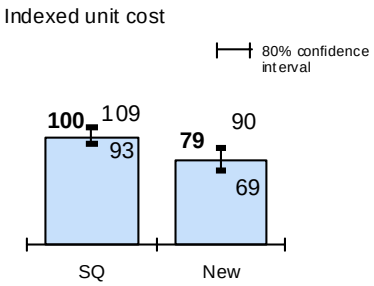
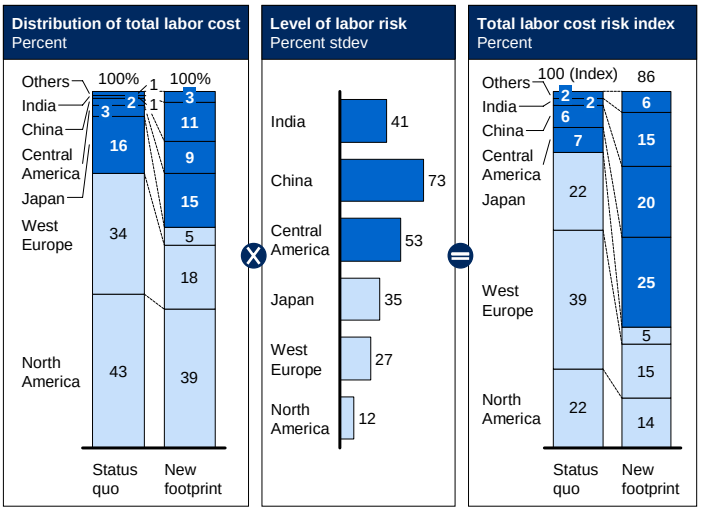


Exhibit 2. Geographic shift of labor risk



Correcting bias in the expected value

However, this is not the full story. There are many additional risks – for instance political and macroeconomic risks, supply chain/transportation risks, risk of quality flaws – which have not so far been included. What is more, these risks are higher in the unfamiliar new footprint than in the current footprint. The company used best available data to specifically estimate the most significant of these risks which would be radically different in the new footprint versus the status quo. Incorporating these risks actually raised the expected total landed cost of the new footprint from 79 to 84.

That's right. The original estimate of the expected total landed cost had to be changed and the overall economics became less attractive than before. This was not the result of shoddy calculation of the "expected" cost, but an example of well-known human biases of dealing with uncertainty. People will anchor around the perceived most likely value when calculating a point estimate: most likely no Asian country's economy will collapse, most likely the plan to ensure quality will be adequate, most likely there will be no debilitating transport hub labor disruption. However, the small likelihood but large impact of each of these events chips away at the expected value. What is more, given enough of such individually unlikely risks, it is quite likely that some of them will strike. Financial institutions have lived this reality for a long time, for instance making allowances for credit writeoffs (though as the recent subprime crisis has indicated, sometimes not going far enough!), but many industrial companies thinking about risks and uncertainties fall into the trap. It is one of the reasons for the familiar experience that nearly all major projects go over schedule and over budget. Going to the effort of quantifying the important risks combats this tendency at the footprint choice stage rather than creating surprises later on.

The unknown unknowns

Even this is not the whole story. There is a whole slew of additional, hopefully very unlikely risks, that may affect either the status quo or the new footprint. It is quite plausible that both the 100 and 84 figures for total costs are somewhat biased as a result. The issue of dealing with the "unknown unknown" risks is very timely, and, especially in the context of financial institutions, dealt with engagingly by Nicholas Nassim Taleb in his recent book, *The Black Swan*, and Riccardo Rebonato in his book, *The Plight of the Fortune Tellers*. The good news is that compared to financial institutions seeking to assure solvency, the issue is of less concern when one is merely trying to make the best choice between several footprint options—provided one is confident the key risks which are different between options have been taken into account.

The stealth benefit of flexibility

There is a compensating factor to manufacturing footprint risk which is often equally neglected. Companies will calculate the economics of their footprint – indeed, of any strategic move or major investment – using the best possible assumptions about uncertainties. However, as these uncertainties resolve, the actual management team will make value-maximizing decisions. A mining company reacting to high commodity prices today by investing in opening another mine will slow down or reduce the scope of the project if commodity prices decrease faster than expected. If instead they zoom up even faster, the company will rationally invest more in bringing the mine up to full production faster than planned. All of these imply the mine is more valuable than merely plugging in the new commodity price assumption into the original model would suggest.

In the case of project investments or strategic decisions, this is the idea behind real options (see, for instance, the book *Real Options* by Lenos Trigeorgis). The above mine's calculated value

(NPV of future cash flows) is increased by a curtailment or abandonment option (basically, not throwing good money after bad), and also by an acceleration/expansion option. In the case of this mine, these two options added another 50% to the value of the project.

Ramping up or down in response to demand

In the case of manufacturing footprints, in addition to these standard real options, there is often significant "stealth value" hidden in the operational flexibility to ramp production up and down in different areas of the network and move output around the globe based on demand. Energy companies do this is a very systematic way, for instance refineries optimizing their output mix based on current prices for different petro products. But manufacturers with worldwide, broad diversified footprints can also have significant flexibility. In a simple case, if a product is manufactured in two locations and demand is lower than expected, the more expensive location is the one that will scale down, and vice versa (see Exhibit 3). We call this "within four walls" optimization – a simple decision by a manager in one geography or one plant to adapt rationally to changing conditions. In a more complex case (see Exhibit 4), based for instance on how demand, transportation costs, and Fx evolve in North and Central America and Europe, a manufacturer with plants in all three regions can optimize from where to serve excess demand. This illustration is only for one product; optimizing the product mix adds another flexibility opportunity. As opposed to the "within four walls" example, this flexibility requires a true portfolio approach to the footprint.

Exhibit 3. Simple case of adjusting production to demand – "Within four walls"

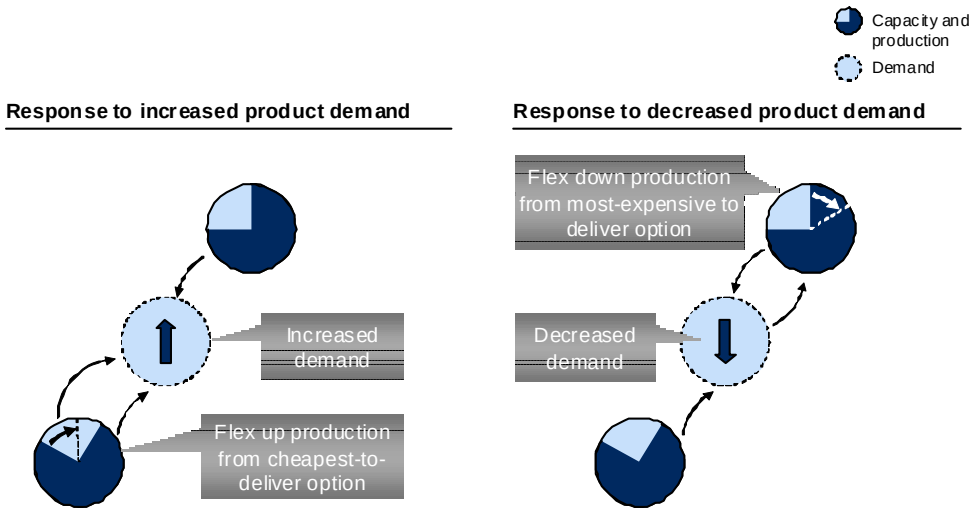
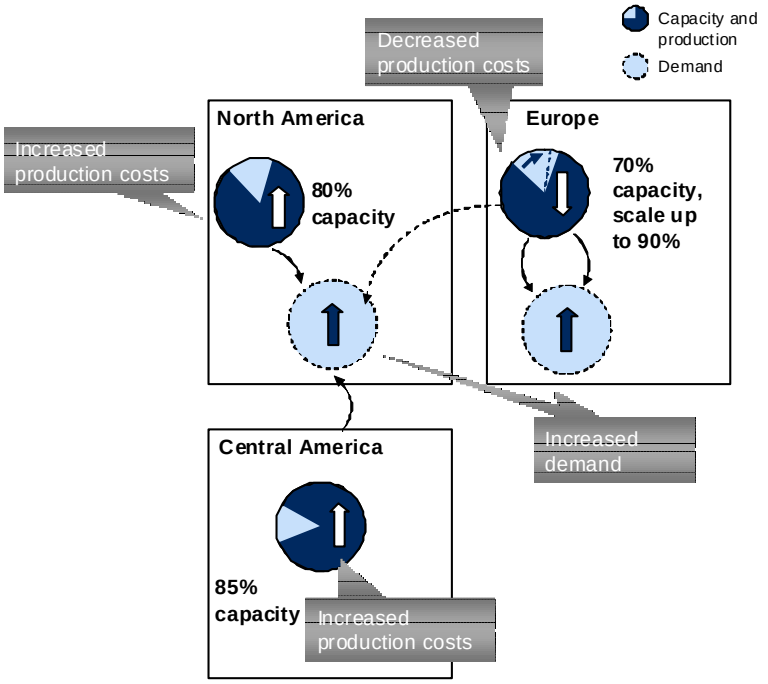


Exhibit 4. More complex production optimization – a portfolio approach



This might all seem like an abstract what-if modeling exercise, but experience shows that this flexibility makes a difference and can change what is the footprint "right answer". A recreational products manufacturer traditionally estimated demand for its products each year in the pre-season. It ran a short single production run and shipped the product to dealers across the country. However, actual demand was highly dependent on the season's weather in each area, and hence there were significant lost sales from not having enough product in one area and having to clear out excess product in another. It turned out that a split production run, with a percentage of output manufactured significantly more expensively in mid-season and delivered to where demand was high was a more economical approach, due to the greater flexibility it allowed.

The same manufacturer as discussed in Exhibit 1 discovered that the proposed new footprint, being more diversified into low-cost countries, provided significantly more operational flexibility than the status quo to scale production up and down as needed, and to respond more inexpensively to uncertain demand for the final product in Asia. This benefit of flexibility, once properly quantified, amounted to a reduction by 32% of the total risk in the new footprint versus the old – more than enough to compensate for the extra economic and political risk. Of this 32%, over one third came from going beyond the "within four walls" approach to true manufacturing portfolio flexibility.

The importance of competitive positioning

Frequently, one of the main drivers to push a manufacturer to take the risk to move to a new footprint is fear – fear that the competition is further ahead on the drive to lowest cost production, and that one needs to follow (or leapfrog) to preserve competitiveness.

Not all companies, however, take the time to really understand the competitor's footprint, its risks, and the import that has on industry competitive position. The fact that a competitor may have an advantaged cost position is unfortunate, but if industry structure is stable, may not be worth the investment or risk of playing at Achilles and the tortoise. In fact, it may provoke rational or irrational competitive reaction that can easily destroy much more value than the original cost savings at stake. On the other hand, in technologically evolving commodity industries, the opposite may well be true: a computer components manufacturer does not have the luxury of avoiding Moore's Law for long.

More insidiously, industry structure can have a huge impact on the risks. For instance[2], in 2000, General Motors appeared to have minimal Yen currency risk – a total exposure of about $30 million. However, a depreciation of the Yen would make Japanese car makers' cost structure significantly more attractive. If this cost difference were fully passed through on price by the Japanese and G.M. did not react, it would translate to several percent share erosion for G.M. Ultimately, therefore, a difference in G.M.'s American footprint and its competitors' Japanese footprint turned out to carry a hidden but real economic exposure of $300-400 million to the Yen for G.M., ten times as much as the nominal exposure. In other words, the G.M. footprint already carried Yen risk, indirectly through industry structure. On the flip side, through diversifying production around the world – including the Toyota-G.M. NUMMI joint venture in California, Japanese car makers have been reducing their direct exposure to Yen appreciation, and indirectly decreasing U.S. automakers indirect competitive exposures to the Yen as a result.

What should companies do?

As the above examples point out, appropriately taking into account all of these factors in making manufacturing footprint decisions is not just a bean-counting exercise. First, it can change the decision. A lower-cost footprint at first glance may no longer be as attractive once significantly greater risks are taken into account. Conversely, a more costly or more risky footprint might provide sufficiently more flexibility to be worth it. Competitive factors may change the cost, risk, and flexibility picture altogether.

Second, the effort itself focuses management attention on value-creating areas. Understanding the risks, sources of flexibility, and competitive dimensions in particular allows management to invest greater preparation to those questions that will sway the optimal choice, and once a decision is made, deploy attention to precisely those areas where value leakage might occur.

However, given the wide range of footprint choices that different companies face, there is no single path to follow to get to the right answer. There are a number of approaches or tools which have repeatedly been useful, but in order to provide the most "bang for the buck" and avoid overkill, we have found it helpful to divide them into several phases with explicit stage-gate processes between them:

[2] This example taken from the HBR case, *Foreign Exchange Hedging Strategies at General Motors: Competitive Exposures*, by Desai and Veblen (2005)

Phase 1. Framing the case for change and key constraints

The 1st goal is to understand what are the issues with the current footprint. This means being explicit about what concerns about capacity, cost, risk, flexibility, or competitive positioning are driving the desire to explore footprint options. A key step in this phase is comparing one's own current footprint with competitors. This involves preparing reasonably detailed cost buildups (including suppliers' cost breakdowns) for oneself as well as – to whatever extent possible – for competitors. The capacity and cost comparisons follow immediately from this fact base, but it also allows comparing the risks and flexibility opportunities between footprints as well. Is your company more sensitive to an economic downturn or to Fx devaluation than a competitor? Is one competitor more flexible in response to differences in regional demand? There is a well-developed methodology of workshop-driven risk mapping and prioritization which helps surface the key issues and differences.

In parallel it is helpful to clearly articulate the level of constraints that exist to pursuing a new footprint. Is major production delocalization to a low cost country a feasible option, or do labor constraints mean the current footprint stays essentially unchanged and the only freedom is where to eventually build a new plant? Is it feasible to change product mix on the fly or not? Is there an upper bound on the investment cost or disruption time frame that any considered option needs to satisfy?

Stage-gate 1. If the level of risk/uncertainty is high and the constraints sufficiently mild to allow exploring genuinely different footprints, it makes sense to continue to Phase 2. If the constraints are overwhelming, it is typically much more effective to focus the output of the risk and competitive analysis to targeted improvements to the status quo. With the additional information available after Phase 1, it tends to be easier to build a robust business case for such improvements than before, but a more extensive footprint optimization effort is unhelpful if there is not enough freedom to optimize.

Phase 2. Comparing footprint options

At this point, the stage is set to explicitly define a handful of new footprint options, compatible with the constraints identified, and explicitly compare these options on capacity, cost, risk, flexibility, and impact on competitive positioning. A key tool at this point is building a probabilistic model for footprint economics, including risks and flexibility. In short, the goal is the output of Exhibits 1 and 2, if applicable including the logic of Exhibits 3 and 4 to make sure operational flexibility is adequately represented. The starting point are the cost buildups from Phase 1, but frequently some deep dives are needed on key risk factors, for instance to understand the nature of political and macroeconomic risks in certain countries, or to analyze the microeconomic impact on supply and demand of currency risk.

In cases where there is a clear cost versus risk versus flexibility tradeoff, there are techniques to actually quantify the financial cost of uncertainty based on the financial needs of the company as a whole, for instance to help choose whether a significant reduction in the 80% confidence interval is worth a slight increase in expected cost.

Stress-testing with targeted scenarios on key assumptions, above and beyond the probabilistic modeling described above, is often helpful as well, both to test situations where data is not sufficient to estimate probabilities, as well as to do "what-if" analysis to give management comfort that implications would not be catastrophic.

Stage gate 2. At this point, there is often a clear winner among the footprint options. In that case, it is best to move to the value optimization phase – drawing conclusions from the analysis to

identify which risks should be mitigated, what flexibility makes sense to invest in, and where to invest management time. If execution risks of the transition have been identified as a key lever, it is here where piloting or scale decisions need to be made. If there is no clear winner, move on to Phase 3.

Phase 3. Zeroing in on the optimal footprint.

In some cases, at this point it is clear that significant improvement can be reached versus the status quo, but the cost-risk-flexibility tradeoff is significant and the discrete options considered thus far do not appear to have zeroed in on the perfect tradeoff. To address this, there are analytical optimization techniques which allow tweaking the parameters of the footprint options (within constraints) to reach the optimal blend. These techniques are typically computationally quite intensive (especially where the number of products or geographies in the footprint is substantial), but can uncover significant value where the level of uncertainty and value of flexibility are high.

* * *

Manufacturing footprint redesign is one of the largest-scale and largest-impact transformations that a manufacturer can undergo. Done well, it can find the best sweet spot for capacity and growth potential, cost, risk, flexibility, and competitive positioning. A tailored approach, bringing the best from a variety of operational, financial, and strategic decisionmaking disciplines, is the key to doing it right.

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