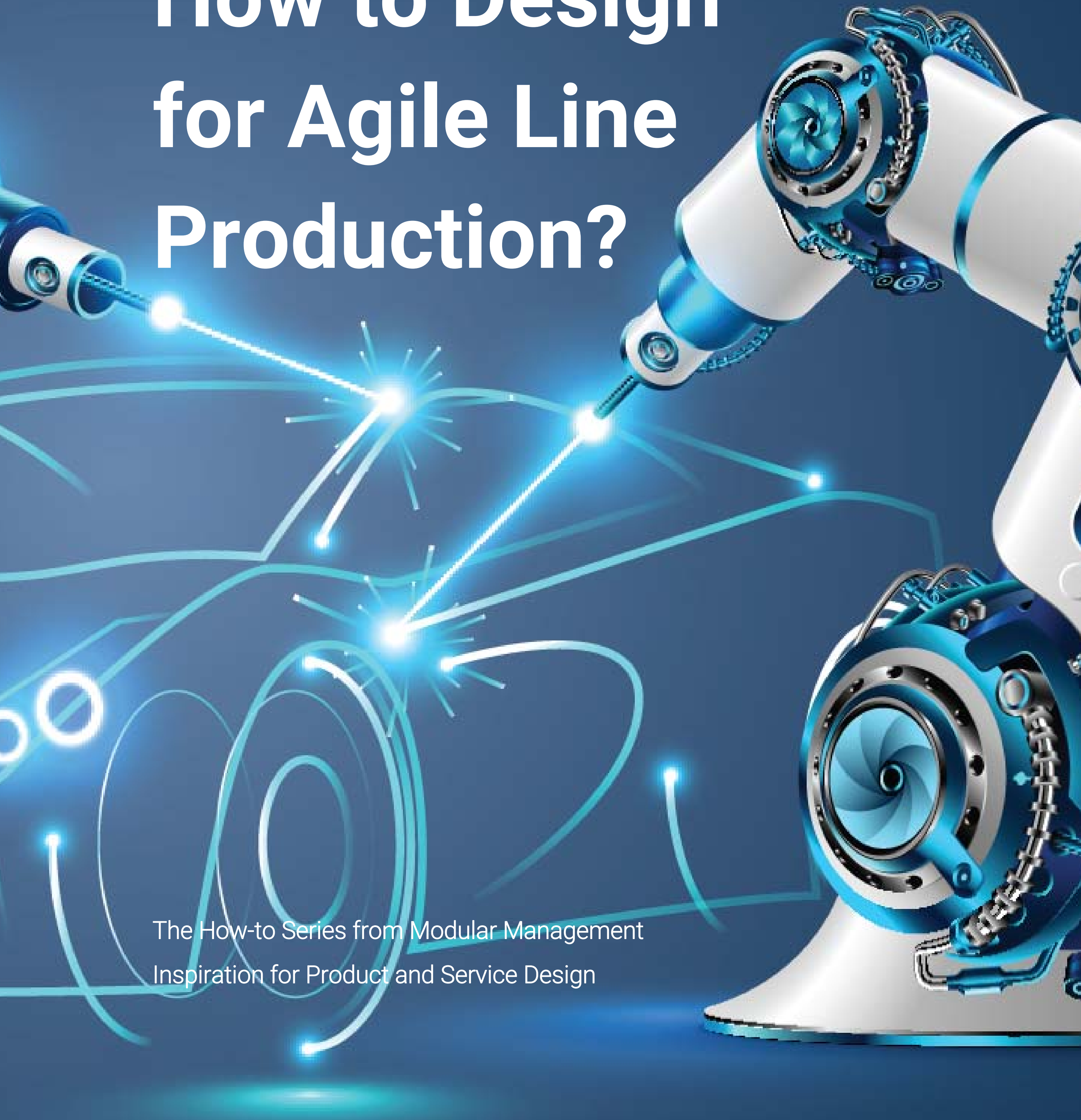
Modular Management®

How to Design for Agile Line Production?



The How-to Series from Modular Management

Inspiration for Product and Service Design

Agile, Customized and Lean

Agile production and mass customization are powerful concepts that line producers often find hard to realize. Many producers struggle to simultaneously:

- Ensure lean, operational excellence.
- Innovate and renew products fast enough to stay at the forefront of global competition.
- Offer the product variance and uniqueness needed to appeal to many customers.

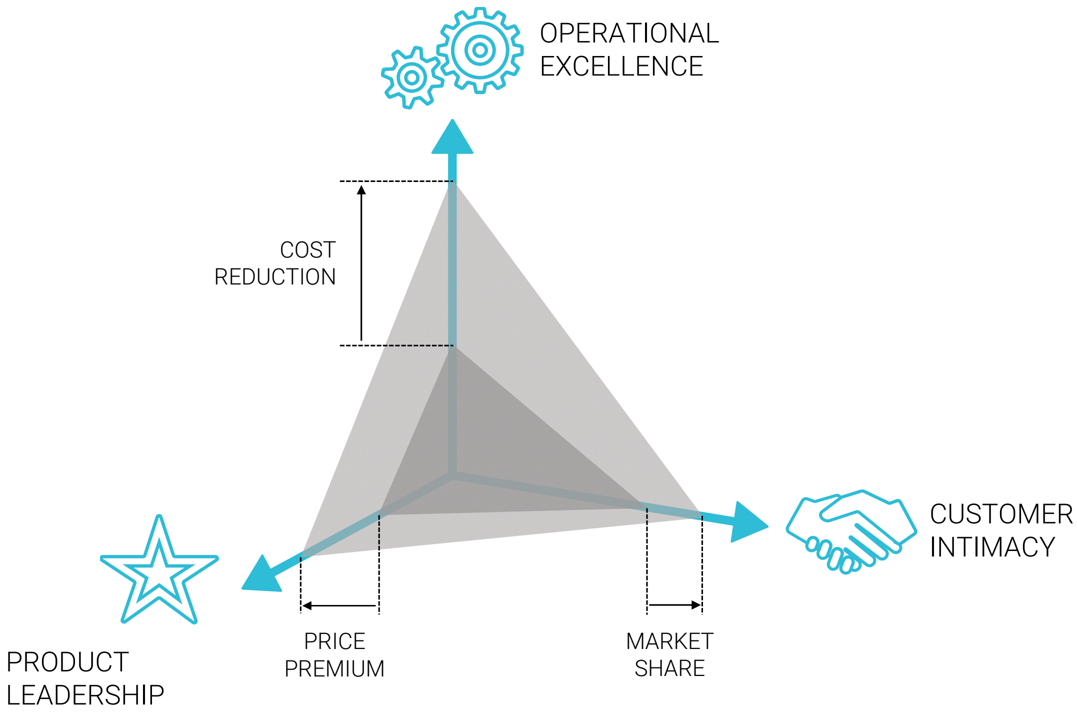


Figure 1: Business Fundamentals as Inspired by Treacy & Wiersema (1995)

So, how can you make mass customized products and secure business fundamentals? How can you design for agile line production? Here are a few ideas.

Mass Production Mode?

Womack, Jones and Roos spread the concept of lean production in *The Machine that Changed the World* (1991). Despite the benefits of lean, many line producers have ended up in a kind of twentieth-century mass production mode, both mentally and physically.

In order to stay competitive, producers have worked hard on renewal rates and product variance – and suboptimized manufacturing. The resulting challenges include:

- Too many production lines used to produce different product families.
- Many lines suboptimized. Some run with low efficiency, due to low demand and under-utilization, while others suffer varying quality (third shift symptom), significant re-planning and long lead times due to over-utilization. Long lead times are often the most damaging consequence, with volumes lost when customers turn to competitors instead of waiting, and non-availability costs are high as a result.
- Batched production and poor responsiveness to actual customer demand, plus long downtime when changing a line between products.
- Major pains when phasing in new products.

Lean, agile and customized products are not mutually exclusive. If you feel a bit stuck in a kind of mass production mode, you're not alone. Read on.

Signs of Mass Production Mode

First, the diagnosis.

There are typically three signs of mass production:

1. Multiple Dedicated Lines
   The most obvious sign is having multiple dedicated lines for different product families. Of course, significantly different product categories, such as bicycles and motorcycles, will probably need different assembly lines. But mountain bikes, race bikes, city bikes and three-wheel bikes should be mixed on the same line.

2. Batched Production
   Even if mixed production is achieved on the same line, having to produce in batch is another sign of mass production. This is almost the same as having dedicated lines, but the line is dedicated for a certain product for a certain period of time, and then changed over to be dedicated for another product for the next batch.

Both multiple dedicated lines and batched production result in a large stock of finished goods, long lead times and lost volumes due to the non-availability of correct product. Dedicated lines also reduce capacity when adapting to changes in the volume mix, leading to unnecessary under- and overutilization. And that’s not all.

3. Pain When Introducing New Products

> This aspect is subtler. Even the most lean and agile company will have to adapt when introducing new products, for example by introducing new tools, and the line and line-feeding sub-assemblies will have to be occasionally rebalanced. But where the lean and agile company succeeds in isolating these changes to specific areas, keeping the majority of the line intact, the mass production company needs to shut down the line for weeks, even months, to rebuild.

The mass production company essentially suffers from product variance and renewal, while the lean and agile company uses product variance and renewal as competitive weapons to better target individual customization and effectively meet rapidly changing customer needs.

Figure 2: En Masse and Pretty Much the Same

Why are Companies Still in Mass Production Mode?

In our experience, the most fundamental reason for getting stuck in mass production mode is suboptimized cost and performance management. Signs to watch out for include:

- Focus on unit cost instead of total cost.
- Theoretical and abstract accounting-driven cost management, instead of concrete performance management of quality, lead time and efficiency in indirect and direct operations.

Figure 3: Focus on Total Cost not Unit Cost

Focus on unit cost often involves only a sample of models and accounting methods that look at direct cost, while treating indirect cost as distributed overhead. This drives behavior to push down direct cost for sample models and push up output – and, in the worst case, output of sample models only.

This type of performance management can lead to a number of undesirable results: unnecessary design variation and growing part number count; a tendency to do excessive theoretical planning; batch production, or production divided on separate dedicated lines to maximize theoretical output; excessive stocking, storing and material handling; deteriorating quality; huge variation in lead time for actual customer orders; and poor cost performance across the entire range of products.

Not great.

Another fundamental reason for getting stuck in mass production mode is product design.

Product assortments often become complex and disconnected due to mergers and acquisitions, frequent product introductions, limited removal of old products and a tendency to design products 'one-by-one.' Sample model focused cost engineering makes things even worse, and it becomes extremely hard, if not impossible, to realize agile line production.

Misguided management and design factors can lead organizations to hold on to mass production mode, even if they know it's really not working. The unavoidable result is suboptimization.

The cure?

How to Exit Mass Production Mode?

If mass production mode is the problem, two things can help organizations get out of twentieth-century mass production and into the twenty-first century where agile meets lean:

1. Change of Thinking
    a. Holistic cost optimization beyond direct cost. This involves income, capital and indirect costs.
    b. Focus on optimizing the correct product flow, i.e. the products that have actually been ordered by customers.

2. Modular Product Architecture
    Experience shows that products manufactured in a mass production system often need to be redesigned, or at least modified, for single-piece mixed production on one and the same line. The product assortment has simply become too complex and disharmonized to produce optimally, and it's probably more than time for a modular product architecture.

The Power of Modularity

When executed holistically, modularity can both support a large product range (economy of scope) and limit the number of individual product parts and related engineering work (economy of scale).

A modular product gets disaggregated into several modules, each of them made available in different variants. In this disaggregation process, each module has a distinct function, or task, and all modules deliver on a specific strategy. Each one has a specific role to play in terms of operational excellence, customer intimacy and product leadership.

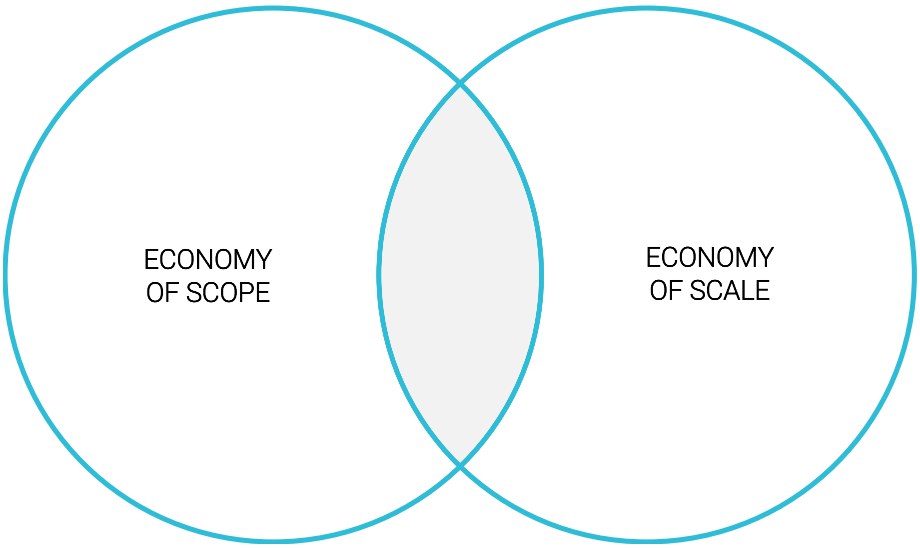


Figure 4: Modularity Enables Economies of Both Scope and Scale

Basic module strategies are linked to the business fundamentals identified by Treacy & Wiersema in *The Discipline of Market Leaders* (1995). Treacy & Wiersema defined three axes that need to be addressed by all companies:

AXIS 1: Operational Excellence

Modules with low variance and stability that run in large volumes over long time – perfect for dedicated mechanization or low-cost country production.

AXIS 2: Customer Intimacy

Modules with high variance and frequent changes in geometry, styling, finish, etc. – suitable for manual or highly flexible production close to final assembly.

AXIS 3: Product Leadership

Modules subject to more fundamental design or technology changes – suited to manual or highly flexible production, close to R&D centres, or by strategic suppliers.

This modular disaggregation, when executed holistically, opens up for a wide choice of production strategies: make or buy, single or multiple sources, global or local sources, supply to stock or supply to order, carry-over or fast renewal. Modularity also supports more specific and tactical aspects, such as preferred manufacturing technologies, standardized production reference systems, standard interface to production line carriers or even the maximum size of pressed metal parts.

Features of Modular Design

Total part number count drives cost and experience has shown that modular design can reduce this KPI 50-75%.

How?

The secret lies in a controlled assortment of module variants for each module, and the ability to combine variants into an enormous assortment of end products. Total part number count is a critical measure for optimizing material flow on a single-piece mixed production line.

The same goes for the introduction rate of part numbers. With modular products, the design changes needed for a new product function, feature or performance value don't create a wave of complexity. Changes can be isolated to specific modules, production tools and assembly areas.

Interface are key to modular design, or rather a modular product architecture. While modules come in required variants, and are allowed to live and change over time, interfaces should be kept as standardized and stable as possible.

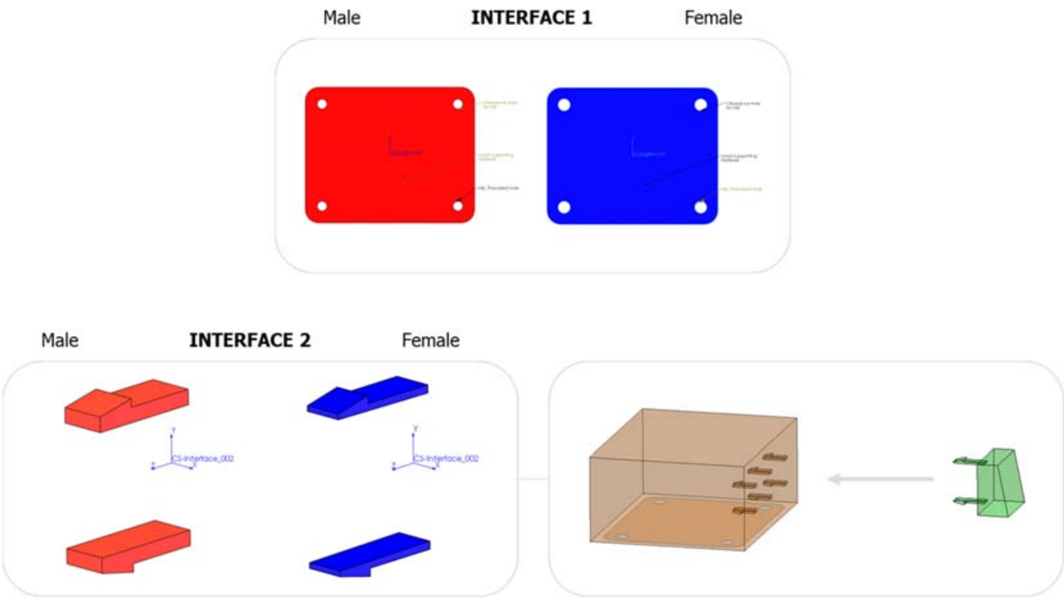


Figure 5: Examples of Standardized Mechanical Interfaces

Standardized interfaces not only allow for combinations of different variants. From an agile line production perspective, some interfaces can also be used by manufacturing equipment such as jigs, carriers, etc. Standardized interfaces enable any variant, current or future, to be set-up in the same way.

Standardized interfaces enable standard operations for a wide variety of products. It doesn't matter which combination of variants are being assembled, they're always assembled the same way.

A modular product architecture also enables greater flexibility in separating sub-assemblies from the main assembly line. Even if the main line is superior in efficiency, it can be advantageous to protect the main line balance by lifting out modules with varying assembly time to decoupled pre-assembly areas. The pre-assembly area produces different variants in main line sequence, or to Kanban, without variance losses. And since all variants are assembled on the main line in the same way, without variance losses, total system performance is optimized.

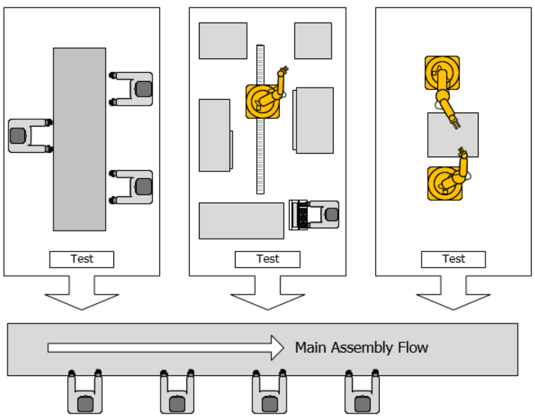


Figure 6: Main Line and Feeding Pre-assemblies

Where variance is high, or changes frequent, separate pre-assembly areas should be used to protect the main assembly line from losses and frequent design changes – even if the main assembly line has superior theoretical efficiency.

The best modular product enables variance, uniqueness and frequent refreshing, both in agreed areas of the product and according to agreed rules. And the modular product architecture, with its standardized interfaces, is an asset so valuable for the entire company that it should be governed by top management.

Case 1. Mass Production Versus One-Piece Flow

In our first case, a factory in Northern Europe is in trouble.

The factory belongs to a major global white-goods producer and manufactures millions of units per year on a number of dedicated lines. Analysis is under way to move 80% of this volume to a Chinese plant, and in an attempt to save the factory, a new high-end product introduction is planned. Both factory and R&D managers, however, realize that more needs to be done; they need a major change in both production set-up and design principles.

First, a new production set-up is needed to deal with the shift from a million units per year, produced in batches of hundreds or even thousands, to a couple of hundred thousand units per year produced in batches of ten or less. This also demands new ways of planning and physically managing production and material, because multiple dedicated assembly lines are no longer economically feasible.

Second, having tens of product variants per product family is insufficient for demanding high-end customers. The producer needs to diversify into hundreds of variants and renew frequently. Average annual volume per product variant is expected to drop from 10 000 to a couple of hundred, and average life-time volume from 20 000 to 500. The analysis shows that a paradigm shift is needed to reduce cost, not least for R&D and introduction cost per product variant.

The decision is taken to apply a modular product architecture to the new high-end product. An extensive assortment can then be created from different combinations of a limited number of module variants, new module variants can be added and others renewed every year. Also, most of the key interfaces should be able to survive more than ten years of continuous product development.

This Northern European factory has previously experimented with multiple different line set-ups. Their conclusion is clear: a large line is superior to several small lines in terms of quality and efficiency. This is quite natural, since one large line gets more improvement attention, can absorb more investments and runs at half the tact time compared to two smaller lines. They also conclude that as much as possible should be made on the line, since pre-assemblies are less efficient than on the tacted line. The final decision turns out to be a compromise. The entire new assortment will be produced on one big line, but three main sub-assemblies with high variance will be separated into their own pre-assembly areas to avoid variance losses on the main line.

During the first year, 400 product variants are introduced on the line, a figure deemed impossible before modularization. Some level of batch production is maintained, but the largest batch is only around 10 units. All production is now to order and finished goods stock has been eliminated.

Within a couple of years, more than 1 000 product variants are produced and this new high-end product becomes the company's most profitable, in terms of gross margin, ever.

Case 2: It's Not Just About Direct Material Cost

In our second case, direct material cost obstructs the view at a high-volume consumer goods manufacturer.

Direct material is often a big part of the cost for a high-volume producer. Experience shows that a consistent outsourcing strategy can drive up direct material to around 80% of COGS, and a few more percent on direct material is normally unacceptable under any conditions. More commonly, a 2-5% reduction of direct cost is expected every year.

At this high-volume consumer goods manufacturer, a dedicated low-volume assembly line produces around 30 000 units/year. The product is old and a decade of cost reductions have trimmed the product cost – and resulted in a warranty cost close to 4% of income. Despite this, the product is still profitable thanks to its uniqueness and specific UK customer demand, even though the low volume makes it uninteresting to invest in any substantial renewal.

The so-called 'UK assembly line' is normally operated in one shift. During one month of peak demand it's increased to two shifts, and for two months it's paused due to low demand. Assembly efficiency is just above 70% (number of stations x cycle time / ideal assembly time), as compared to more than 80% for their best-in-class assembly lines. Direct material cost is around 90 EUR and direct labour stands slightly above 10 EUR.

If the company was to add this product into the modular assortment, by changing the chassis, some other parts and trying to solve some of the worst warranty issues, it would increase direct material cost by around 8-10 EUR. Only 1 EUR would be saved in direct labour from the move to a more efficient high-volume line. Unthinkable.

But is it really unthinkable? Trick is to look at cost on the right level.

The total structure cost for the UK line was around 600 000 EUR/year. In structure cost we include cost of floor space, indirect line personnel, line maintenance, cost of capital and some administration costs.

In summary, structure cost savings for the modular redesign would be 20 EUR/unit compared to the 8-10 EUR direct cost add-on; a saving of at least 10 EUR/unit. Modular and agile line benefits, discovered when looking at the total structure cost instead of direct cost alone, make the well-executed change thinkable and profitable.

Case 3. Dedicated Versus Flexible Lines

In a comparatively low-volume industry, a company assembles three different product families on three dedicated assembly lines. Product families A, B and C cannot be produced on the same line due to different structural design principles and low commonality of parts.

Figure 7: Demand and Capacity (Dotted in red) for the Three Dedicated Assembly Lines

Demand for product families B and C is generally low and variable over the year. These products also have a low value-to-volume ratio, meaning they are expensive to transport and should be manufactured as close to the final customer as possible. However, low and varying volume means it's not feasible to invest in local production for B and C on all markets, and that leads to a competitive disadvantage where significant transport is necessary.

Product Family A also has variable but relatively high demand. The assembly line for A, in the main European plant, doesn't have enough capacity to handle peak demand even on 3-shift, so 25% of the volume is not assembled on the line, but in a special stationary assembly area where assembly time and cost is 25% higher. During the 6 months of peak demand, many orders are lost due to long delivery times.

So, the decision is taken to re-design all three product families. The new modular products enable harmonization of structural design principles and a reduction of part numbers. Only two lines are needed to cover demand and, by going up from the normal 2-shift to a 3-shift for a quarter of the year, it's possible to keep standard delivery time over the whole year.

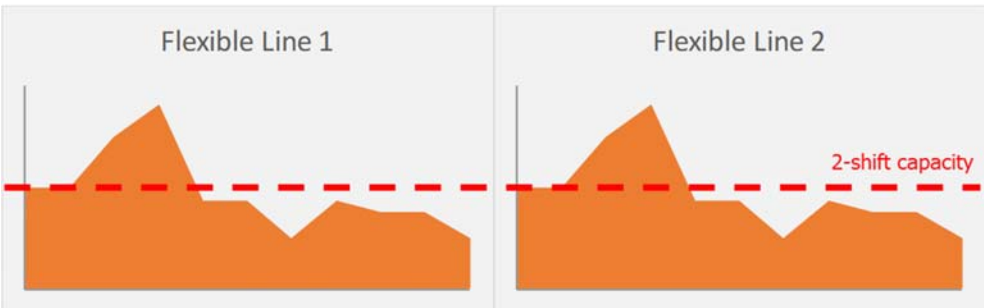


Figure 8: Demand and Capacity (Dotted in red) for the two new Flexible Assembly Lines

Material management is also dramatically improved. 80% of the material is in fixed facades and the remainder is managed by order-Kanban directly to the assembly lines.

Finally, it’s a lot easier to localize assembly of the full assortment closer to the end customers, eliminating the previous competitive disadvantage of higher shipping costs.

Conclusion: How to Design for Agile Line Production?

At the beginning of this paper, we assumed that many line producers are operating in a kind of twentieth-century mass production mode. Typical signs are multiple production lines dedicated to specific products, batch production and major pains when shifting over to new products.

Our experience suggests that the remedies are twofold:

1. Redesign your products to become truly modular.

2. Change your mindset to focus on the total profitability and flow of actually ordered products.

Don’t stare at direct cost. If you can increase product availability, or reduce total structure cost by reducing the number of lines, it’s often worth it. And at the end of the day – thanks to modularization – volume per part effects, production process harmonization and part number reduction all have the potential to reduce direct cost too.

Imagine having the same line set-up everywhere.

Imagine being able to produce your entire assortment directly to order, from that single line set-up, and never having to suffer from the 'wrong' volume mix, non-available product here and suboptimized production lines there.

Imagine being able to shift volumes between sites with full flexibility.

Imagine innovating, refreshing and creating unique products without your production system slowing you down or becoming a roadblock. All your continuous improvements can spread without friction between sites, with new products first implemented on one pilot line and then quickly copied to all manufacturing sites.

Modularity is an enabler for lean and agile line production. So, thanks for reading and info@modularmanagement.com if you're curious to find out more.

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