IBM Global Business Services
Executive Report

Electronics Industry

IBM Institute for Business Value

The new software-defined supply chain

Preparing for the disruptive transformation of Electronics design and manufacturing

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By Paul Brody and Veena Pureswaran

Adaptability is a hallmark of the Electronics industry, with its history of changes ranging from incremental to radical. Traditional manufacturing has shaped worldwide trade flows and built industry structures based on economies of scale, as well as supply chains that are both multi-tiered and global. But today, three new technology revolutions – 3D printing, intelligent robotics and open source electronics – promise unprecedented supply chain upheaval. In this report, we show that these newer technologies will produce an average 23 percent unit cost benefit and reduce entry barriers by an astounding 90 percent. Yet half of our survey sample has no manufacturing strategy to manage the impact of digitization. To compete in this fast-approaching future, companies and governments must understand and prepare for this new software-defined supply chain.

As the twentieth century dawned, Ford Motor Company set the rules for modern manufacturing. Production of the Model T used interchangeable parts on an assembly line to usher in an era of standardization that has continued with refinement for more than one hundred years. By the 1920's, competitors were extending Ford's mass production model and gaining market share, thanks to the use of sub-contractors, modularization and common parts across models and even brands.

Over time, three major manufacturing and product design trends emerged, shaped by the physical reality of the industrial supply chain: parts continued to become more standardized; assembly has continuously shifted toward modules from basic components; and complex mechanical controls continue to be replaced by simplified digital intelligence. More than a century later, these same rules still drive industry strategy, not just in Electronics, but across a variety of manufacturing industries.

Now, the historical rules hardened by a century of experience are being overturned by three emerging technologies: 3D printing, intelligent robotics and open source electronics. Together, these new technologies are creating a manufacturing environment that is driven by digital data. We describe this transformation as moving from a supply chain that is hardware-based to one that is "software-defined."

The result: a reconfigured global supply chain will emerge in the coming decade. It will radically change the nature of manufacturing in the Electronics industry, shifting global trade flows and altering the competitive landscape for both enterprise and government policy makers.

To understand how the competitive landscape of the Electronics industry will change, and how these technologies will impact enterprise investment decisions, we conducted a study comprised of two primary research components: a face-to-face survey of 55 executives in 10 countries and a quantitative model measuring the potential effects of ongoing industry changes. We studied four representative test cases: tearing down products, analyzing their bills of materials and assembly, and then modeling how they would be made and distributed using a software-defined supply chain.

Despite the enormous press coverage that technologies like 3D printing have achieved, we found that manufacturing leaders remain ill-prepared for these transitions. Historical manufacturing trends still drive Electronics industry strategy – for example, although 3D printers allow nearly unlimited customization, most supply chain executives we spoke to still plan to drive increased product and component standardization. By changing the requirements for scale, location and volume, the software-defined supply chain won't just change costs or manufacturing processes, it will effectively up-end the industry structure as we know it.

In this rapidly-changing environment, companies seeking success during this transition will need to change product design and retail strategies; prepare to compete in a new industry landscape; and build extraordinary flexibility into their own supply chains. At the same time, electronics companies are not the only players that will be impacted by this revolution. For government policy makers, there are implications on labor arbitrage, infrastructure requirements, skills development, taxation and intellectual property.

Three rules of product design and manufacturing

Henry Ford famously said that people could have the model T in any color they wanted, so long as it was black. He was onto something profound: *standardization*. When introduced in 1907, a single Model T car took 14 hours to assemble.[1] In 1910, production shifted to an assembly line and by 1914, assembly time had plummeted to just 1.5 hours per car.[2]

Despite the press coverage that technologies like 3D printing receive, manufacturing leaders remain ill-prepared for their impact.

Building on his insights, General Motors and Chrysler quickly learned that multiple car models could be built using many standardized parts and small variations. On the foundation of standardization, manufacturers added a new rule: *modularization*. Assembly of integrated modules from standard components drove productivity even further. It also spawned a new wave of supply chain expansion as vertically integrated enterprises embraced extended supplier networks.

Finally and most recently, a third foundational rule in product design and manufacturing has emerged: *digitization*. However, the purpose of digital systems in manufactured products has not typically been to make them intelligent, but rather to make them simple. Digital control systems on everything from fuel injection to fly-by-wire airplane controls have helped radically simplify products, improve reliability and further drive down costs.

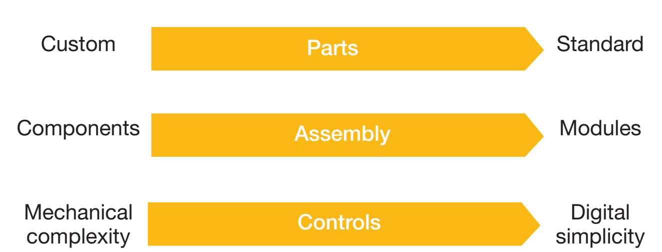
These rules haven't just shaped the processes of product design and manufacturing; they have shaped a century of global trade, investment and employment. Supply chains today are big because standardization supports pursuit of ever-greater economies of scale. Their complexity stems from their dependence on extended networks of suppliers, and as companies chase low-cost assembly labor to help integrate these products, they are increasingly big, complex and global.

In the decades since, three major manufacturing and product design trends have emerged – becoming so ingrained they could even be considered "rules." Parts continue to become more standardized; assembly has continuously shifted toward modules from basic components; and complex mechanical controls continue to be replaced by simplified digital intelligence (see Figure 1).

Methodology: 2013 IBM Manufacturing Executives Study

Our study is comprised of two components:

- One-on-one interviews with thought leaders, academics and industry analysts in Asia, Europe and North America to reveal their current levels of understanding and future readiness to deal with the changing Electronics industry supply chain. The survey includes interviews with 55 executives in 10 countries: Austria, China, Finland, Germany, Japan, Netherlands, Sweden, Taiwan, the United Kingdom and the United States. Respondents represented companies ranging from small enterprises to multi-billion-dollar global corporations.
- Primary research with a team of worldwide experts to model changes to both the manufacturing process and supply chain locations stemming from the impact of three emerging technologies: 3D printing, intelligent robotics and open source electronics. We assembled a team of worldwide experts to undertake four product test cases – sourcing and modeling data on hearing implants, mobile phones, industrial displays and washing machines.



Source: IBM Institute for Business Value analysis.

Figure 1: **Three traditional product design and manufacturing trends of the 20th century were shaped by the physical reality of the industrial supply chain.**

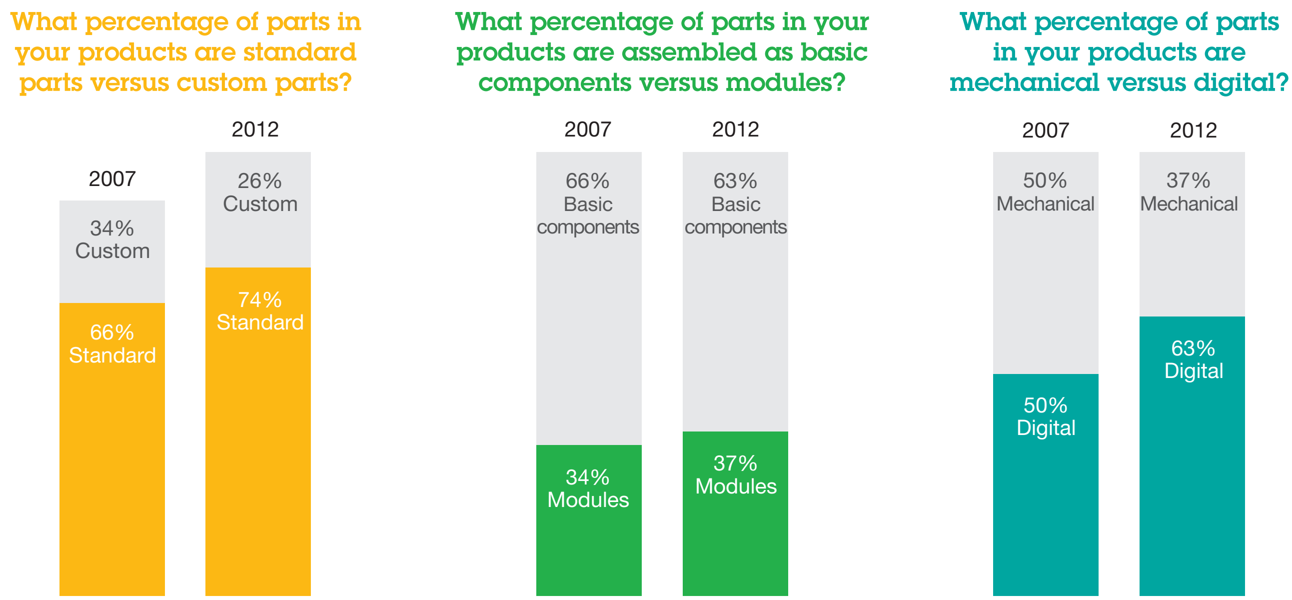
Our survey confirmed that companies are continuing to pursue these same strategies. Respondents told us that in 2007, 66 percent of the parts in their products were standard compared to 34 percent that were custom. In 2013, 74 percent of these same respondents now use standard parts versus custom (see Figure 2). Similarly, more companies are increasing modularization and rapidly replacing mechanical parts with digital controls.

Ongoing adherence to these historical rules of manufacturing has helped to shape global industry structure and trade flows. Three main characteristics of this structure include:

- ***Bigger is better.*** Industry scale keeps growing, with major companies producing multiple millions of units while the average unit cost keeps decreasing.
- ***Supply chains are complex and multi-tiered.*** To support large volumes of production and distribution, supply chains have become more complex and are comprised of many tiers of suppliers and sub-contractors that perform specialized roles such as raw materials supplier, component manufacturer, contract manufacturer/assembler or warehousing.
- ***Production scattered around the world.*** Back in 1913, 75 percent of the world's production was concentrated in only five countries: France, Germany, Russia, the U.K. and the U.S.[3] From this highly-concentrated environment, manufacturing has since become widely distributed around the world. Japan, China and other countries have emerged as major manufacturing centers.

It is clear that these three rules of manufacturing have been wildly successful in creating decades of global prosperity – an obvious benefit of having these rules as the framework of the Electronics industry until now.

But a new era has already been launched. Today – much more rapidly than the technology evolution of the twentieth century – a software-defined design and production cycle is redefining the traditional hardware-driven approach.



Source: IBM Institute for Business Value.

Figure 2: **Electronics executives report ongoing focus on manufacturing approaches that have worked well for more than one hundred years.**

Three technology revolutions

Despite having yielded so much success, the era of big, complex and global supply chains is drawing to a close. A new era is being created by three emerging and converging technology revolutions. 3D printing, intelligent robotics and open source electronics are driving enormous industry changes. Here, we look more closely at each technology to understand its economic and other impacts on both enterprises and governments.

3D printing reverses standardization

The first and most important revolution is 3D printing, also known as additive manufacturing. Very simply, 3D printing uses technology similar to laser and inkjet printing to deposit layers of material on top of each other to build solid objects, one layer at a time. The technology has been maturing rapidly over the last two decades to the point where it is cheap enough for consumers to start buying their own printers.

For enterprises, however, 3D printing isn't just a curiosity, it's a revolution. It frees companies from the need to build standardized parts and pursue economies of scale. To make the same size part, the time and cost is the same for a thousand copies of one part or to print the same part a thousand times. 3D printers also eliminate the need for the intermediate step for most metal and plastic parts: the costly and time-consuming creation of molds. With 3D printing, you can go directly from a design to a part.

3D printing technology has reached an exciting tipping point, with some Electronics companies starting to invest in it as a production technology. The reasons for this include:

- *Rapid reduction in cost* – High-resolution desktop 3D printers are priced at about US$3000 today.[4] The decrease in cost and size of 3D printers, coupled with improved accuracy, strength and materials supported make it a viable technology for makers and manufacturers.
- *Increase in accuracy* – Industrial printers are achieving a resolution of 10 micron with increased strength and finish quality.[5] Geometric freedom in 3D printing allows for more efficient design, lighter products and shorter product design cycles.
- *Increase in variety of supported materials* – While not all materials can be 3D printed, about 30 industrial plastics, resins, metals and bio-materials are supported today, with conductive, dielectric materials and green polymers expected to be printable in ten years.[6]
- *Expiration of critical patents* – Since the expiration of Chuck Hull's 1984 Additive Manufacturing patent in 2009, the open source community has embraced 3D printing, leading to rapid innovation and improvements.[7] Fifty-one critical patents in the industry will expire in the next ten years.[8]

Absent the requirement for economy of scale, 3D printing is expected to fundamentally transform the principles of global mass production (see Figure 3). And yet, just 17 percent of our respondents report that 3D printing's impact on the future of manufacturing is significant "to a very large extent." Perhaps just as surprising, 33 percent characterize this technology as "not significant," which indicates that a substantial portion of manufacturers may be caught off-guard by the rapid changes underway.

Figure 3: **The economics of 3D printing will fundamentally transform the principles of global mass production.**

3D printing technology is already widespread in prototyping and specialized production applications like aerospace and jewelry. As costs fall, we expect it to shift into broad manufacturing. Our study findings forecast that 3D printing costs should fall by 79 percent over the next five years – and by 92 percent over the next decade, making it more cost-effective than all but the largest production runs.

Intelligent robotics reverses modularization

The second technology revolution is intelligent robotics. If 3D printing is the most significant, then robotics is the most surprising. Early robots were barely more than costly machine tools. In the last decade, however, a new and more flexible generation of robots has been integrated into production lines and even adapted to new products. These systems can intelligently pick up items and place them correctly, adapt to variable rates of production flow and pick out correct items using machine "vision." Flexible robotics systems are still costly, however, taking weeks or months to design and configure for each step in the process, and costing upwards of US$200,000 per manufacturing cell.[9]

The newest generation of robots – we call it intelligent robotics – has emerged in the last few years. It delivers another step change in capability and promises to make robotics a main-stream production technology. The newest generation of robots can be deployed for as little as US$25,000 each, and can be set up in and brought into operation in just one day.[10]

Intelligent robots aren't just cheap; they are even more sophisticated than previous generations. They understand object concepts such as production lines and they can be set to tasks without programming and are designed to work safely alongside people in a manufacturing environment.

For manufacturers, the availability of cheap robotics systems eases the search for low-cost assembly labor. While robotics will not replace all – or even most – skilled labor, it does allow for simple assembly operations at very low cost. This not only frees companies from excessively long supply chains, it also makes it possible to assemble products from components without shipping them out to third parties for integration into modules.

Improved sophistication in the next decade is expected to make new generations of robots indispensable in manufacturing. Industrial robot sales have started to rise in recent years as costs declined and capabilities matured. Between 2009 and 2011, for example, an International Federation of Robotics study found that their use in the Electronics industry rose from 18 to 23 percent.[11] A host of improvements to robotic capabilities over time will continue to increase their usefulness, including: adaptive and reconfigurable assembly, safety, dexterous manipulation, correct-by-design manufacturing, unstructured environments and nano-manufacturing.

Open source electronics accelerates digitization

The final revolution is the rise of open source electronics. Over the last decade, consumers and enterprises have become comfortable with open source software. Sharing the work in creating basic capabilities turns out to be very efficient and effective in software, but that has been of little relevance to the makers of embedded chips for most manufactured items. The purpose of embedded chips, however, is to simplify products, not necessarily to make them "smarter." And, the high cost of computing power has pushed manufacturers to design custom electronics that drive cost down by minimizing the sophistication of the embedded chip. Now however, thanks to Moore's law, it is now cheaper and faster to put a fully-integrated computer on every manufactured device than it is to develop a specialized, embedded chip.

Three emerging and converging technology revolutions - 3D printing, intelligent robotics and open source electronics - are transforming the global supply chain.

Consumers have embraced these system-on-a-chip platforms to create open source hardware designs that add intelligence to devices – many of which they can then produce by themselves using 3D printers. Companies and individuals are publishing open source hardware designs using standardized components and developing open source software platforms that replicate typical embedded system functionality. The same positive cycle of peer review and reputation building works as it does for open source software. Indeed, where just a few years ago consumers were sharing just 20 to 50 new open source product designs every month, today we count more than 30,000 new designs every month.[12]

For enterprises, the rise of open source electronics presents a dual opportunity. For the first time, it's possible to shift the "brains" of a device from a hard-wired chip to software that is running on a flexible platform. That means rapid design cycle time. It also means that instead of just using computing power for simplification, the marginal cost of adding significant intelligence to products is now near zero.

Of our respondents, 26 percent said that access to emerging technologies is the primary driver for innovating in an open source model. Tied for the second most-common response were 22 percent each who cited lower R&D costs and shorter time-to-market as their primary drivers to source innovation externally versus internally.

The industry has seen a steady growth in open source components. Respondents report that just 20 percent of products were open source five years ago and in 2013 that percentage had climbed to 33 percent. Open source electronics will bring the power and flexibility of complex control systems to the full range of device types (see Figure 4).

Commoditization of hardware

- Powerful computing capability will become commoditized
- Transforms dynamics of competition – embrace your competitor and consumer

Efficiency

- Huge economic waste for the industry when multiple implementations are developed by different closed design teams
- Means of global market research for new product development

Innovation

- Democratizes innovation. Consumers become product developers
- More rapid innovation from access to faster testing and feedback

Intellectual property

- Trade in design specifications rather than finished products
- Promotes stricter adherence to standards

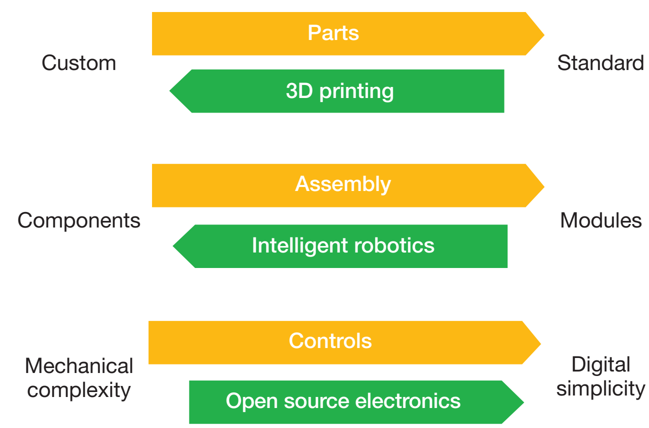
Figure 4: **Key outcomes of manufacturing that is based on open source electronics.**

From hardware-constrained to software-defined

Today, though we often design products in software, the reality is that supply chains are defined by physical and operational constraints. Components cannot be made without first creating molds that are then tested and put into production on specialized machinery. Production lines are carefully built for volume and speed, and production planning systems are designed to minimize the number of times reconfiguration is required. Even the software that controls many modern devices is actually hard-wired into embedded systems that are custom made with months of lead-time. And products often travel thousands of miles before reaching the consumer.

By contrast, 3D printing allows companies to go directly from design to product, all through software and all at the touch of a button. Intelligent robotics uses software to simplify and accelerate assembly activities and open source electronics transforms hard-wired embedded chips into intelligent software platforms.

Each of these disruptive technologies described would, in and of itself, have a tremendous impact on the expansive business of manufacturing, reshaping some of the constraints that define the global supply chain today. But these revolutions are not maturing independently – they are converging because they all share one common characteristic: they are *software-defined* (see Figure 5).



Source: IBM Institute for Business Value analysis

Figure 5: **Traditional product design and manufacturing rules are being rewritten today in the digital era.**

Four product test cases: Measuring the effect of software-defined Electronics production

Forecasts of technology-driven revolutions are notorious for being overly optimistic. The logical question for any manufacturing enterprise to ask in light of these converging revolutions is: When will they be mature enough to change the manufacturing process in a cost-competitive manner?

To answer that question, we launched a research project to understand the impact of these trends in a very specific manner. Rather than focus on generic capabilities, we chose to look at four products, each different in cost, size, volume, personalization and complexity. Individually, each represents real and specific manufacturing and supply chain challenges for enterprises. Collectively, they represent a range of products manufactured for consumer and industrial purposes by the electronics industry. The products span the small and personal to the large, standardized and mechanically complex: a hearing aid, a mobile phone, an industrial LCD display and a washing machine.

For each product, we assessed how feasible it would be to manufacture these items using a new *software-defined* supply chain. We did this by tearing each product down by component, identifying the origin of each component, and then building an integrated view of supply and assembly steps. For each component, we assessed whether or not it could be 3D-printed or have an embedded electronics component replaced with an open source alternative. We assessed each assembly step in the same way, determining if sophisticated skilled labor was required or if it could be assembled with the newest generation of robots.

We conducted this assessment at four points in time starting with a baseline for 2012 using current 3D printing, robotics and open source technologies. To validate our projections, we used 2007 as a historical point of validation using data from five years ago. For the current analysis (2012), we compared existing traditional and digital manufacturing techniques. We then built a forecast for costs and capabilities of these technologies looking out to 2017 and on to 2022, driven by technology roadmaps from leading manufacturers.

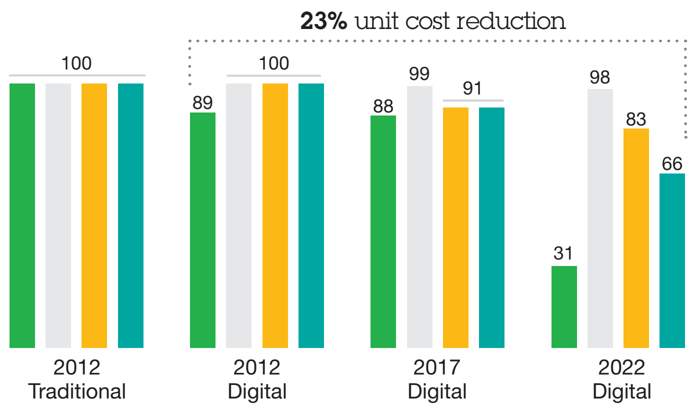
Finally, we asked a simple question of this model: *What is the optimal supply chain required to supply each of these products to consumers and enterprises in North America?*

Modeling results: The era of small, simple and local

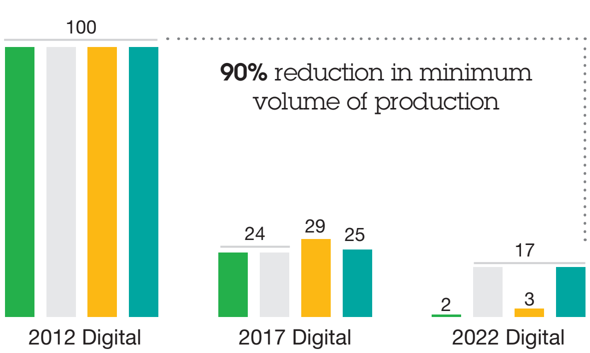
The most critical test that the software-defined supply chain must meet is cost. In every single case we modeled, we found that within five years, a significant portion of every one of these products could be manufactured with a software-defined supply chain – and, doing so would result in lower costs.

Within five years, costs become modestly lower and within ten years, they are 23 percent lower, on average (see Figure 6). Even more dramatic however, is the 90 percent decrease in the minimum economic scale of production required to enter the industry. Surprisingly, though, it is not true that new technologies will offer uniformly "greener" results.

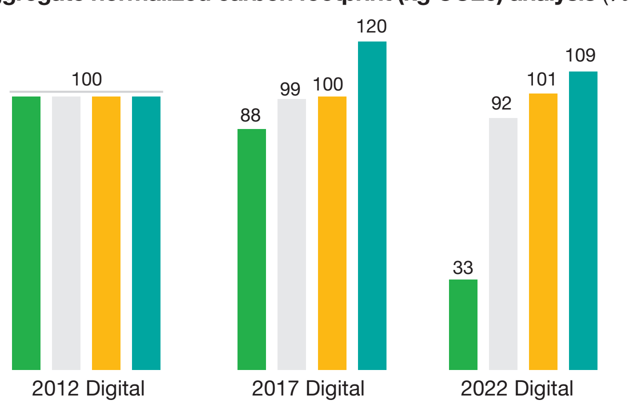
Aggregate normalized unit cost analysis (%)



Aggregate normalized minimum economic scale analysis (%)



Aggregate normalized carbon footprint (kg CO2e) analysis (%)



Source: Econolyst, Mike Watson and Alex Scott, IBM Institute for Business Value

Hearing implant · Mobile phone · Industrial display · Washing machine

Figure 6: **On average for the industry, our analysis shows that the software-defined supply chain is expected to provide a forecasted 23 percent unit cost benefit, a 90 percent reduction in scale requirements and variable benefits in terms of carbon footprint.**

Being cost-competitive is only the beginning. The most astounding finding of this study relates to scale. Software-defined supply chains can be cost-competitive with production volumes up to 98 percent lower than traditional supply chains. Across our model, the average was 75 percent lower within five years and 90 percent lower over a decade.

Taken together, we expect a radical "relocalization" of global manufacturing. Nothing illustrates this better than the detailed case of the hearing aid. Today, it is already cheaper to make significant components of hearing aids using 3D printing. By 2022, hearing aids made with open source electronics and 3D printers will be up to 65 percent cheaper than with traditional manufacturing approaches.

This does not mean that every component can be made using 3D printing or that every assembly step can be conducted using intelligent robotics. Rather, we assessed each component and assembly step individually and we drove the supply chain model to choose the most efficient option. The rapid decline in minimum economic scale is a good indicator of how quickly these new technologies could start to take a very large portion of the total supply chain activities. (More detailed analysis of components and assembly steps can be seen in the supplemental modeling information available at *http://www-935.ibm.com/services/us/gbs/thoughtleadership/software-defined-supply-chain/*).

3D printing and robotic assembly will significantly reduce the need for large supplier networks or vast extended supply chains. The reduced requirement for scale will also have a big impact on the location of production: the optimal manufacturing location by 2022 is regional or local rather than global.

The result of all this is a supply chain that is no longer big, complex, and global. Rather, it will be comparatively small, simple and local.

Change is good, you go first

Indeed, talking about making changes while hesitating to do so seems to sum up the current level of preparation that we observed in our survey of global supply chain leaders at more than 50 top companies. Seventy percent of them admitted to having little or no preparation for a software-defined supply chain.

The picture got bleaker when we asked what they plan to do in the coming decade. Uniformly, the answer is: more of the same. More standardization and more modularization, two strategies that look increasingly obsolete.

For leading global companies to prosper in this new environment, radical change is essential. To see what will be required, the example of one surveyed company is useful. This company is a maker of fast-moving consumer goods (FMCG) that typically produces SKUs in the millions of units and a leader in the adoption of robotics.

By using the newest robots, this FMCG company has cut its cost of manufacturing in Europe to be very close to the cost of manufacturing the same products in China. More important than cost, however, is their approach to customization. This company is preparing for an era when volumes for individual products will be measured in the hundreds or thousands, not millions. It is actively looking at swapping out plastic injection molding systems for 3D printers and determining how product design must change to use the full power of 3D printers. Every part of its product design and engineering organizations is thinking actively about the company's future in a transforming industry structure.

Seventy percent of surveyed supply chain leaders admit to having little or no preparation for a software-defined supply chain

Act now to prosper amid supply chain disruption

Undoubtedly, significant industry disruption is ahead for Electronics companies. The average cost of production using new technologies will be lower and scale requirements to be competitive will be lower. Digital manufacturing will allow a high degree of personalization for products that are cost-competitive with standardized implementations. Cheap robotic assembly will allow parts to be printed in segments – thus eliminating tiers in the supply chain.

For Electronics enterprises, navigating the transition to a software-defined supply chain requires an understanding of its far-reaching implications:

- Product design and retailing will be influenced greatly by interactions with customers
- Competitive dynamics will change radically
- Supply chains will become more simple, flexible and localized.

So what can Electronics companies do now as these new trends accelerate? In short, they will need to change product design and retail strategies; prepare to compete in a new industry landscape; and build extraordinary flexibility into their own supply chains.

Change how you design and sell products

With the expansion of online ecosystems, the repository of customizable design content can only grow. And as labor costs become less influential in choosing manufacturing locations, product demand will drive those locations closer to consumers – making it simpler than ever for consumers to weigh in on product design. Distribution centers may become manufacturing centers for small products that are not overly sophisticated.

How companies sell to increasingly engaged and tech-savvy customers is also going to be different. For example, digital libraries of parts will likely revolutionize how products are sold, just as MP3 files revolutionized the music industry. As product design and retailing is driven by finer market segments, Electronics companies will need to:

- ***Adjust your offerings for new and changing target segments using their input.*** Consumers can be engaged much earlier, more easily and more intensively in the design process, thus blurring the line between product design and product marketing. Existing customer segments may change what they want and companies should discover entirely new segments as well. Stay abreast of changing technologies and customer requirements to innovate your product mix so you can produce what your business customers or target consumer segments are clamoring to buy.
- ***Exploit the affordability of producing customized and personalized products.*** Variations in product design are expected to become more feasible and cost-effective as design ideas become accessible to anyone and the need to produce on a large scale diminishes. And, completely new platforms may emerge that enable efficient, personalized product creation, marketing and sales. Adjust marketing strategy and future investments to accommodate new consumer needs and revisit your portfolio to identify customization opportunities.
- ***Identify both new and vanishing sources of manufacturing profit.*** The competitive advantage from both proprietary design and parts production is expected to erode as basic design blueprints become widely available via open source. Conversely, crowd-sourcing and open source can lead to valuable new ideas for potential products. Identify opportunities for partnering with industries or new entrants that could become "the new face of retail" in manufacturing. And the service parts business will lead the digital transformation, leaving companies unable to generate profits from selling spares.

Implications for government policymakers

The transformation of industry structure will not just affect Electronics companies. Governments will need to act on several fronts to deal with widespread global changes:

- *Find new sources of competitive advantage.* Because low-cost labor will decline as a competitive advantage, new sources must be identified. Policies on education and skills development can support the shift toward both ends of the supply chain.
- *Reassess local economic development policies.* As new value chains emerge, manufacturing will move closer to consumer markets. Governments should evaluate opportunities for new manufacturing companies and industries in their own regions. Support smaller enterprises (rather than massive manufacturing hubs) by re-distributing and re-sizing industrial infrastructure and capital expenditure.
- *Revisit existing tax and customs policies.* Global trade will become less physical and more digital. New global trade flows will require evaluation of imports, duties, taxes and customs, including sales of digital data across national borders. Evaluate opportunities for industries such as transportation and logistics to evolve into different roles in the new industry structure.
- *Refine policies regarding sustainable digital manufacturing.* Additive manufacturing is expected to reduce materials waste, and the rise in local and regional transportation costs will lower transportation costs. However, not all printable materials are bio-degradable. Invest in technologies that are recyclable, provide for materials disposal and drive industry standards for digital manufacturing, including incentives for greener options.
- *Address potential intellectual property (IP) challenges.* The exchange of digital data makes production of anybody's design possible and today, IP protection varies widely by country. Prepare for IP reform and digital rights management by protecting businesses but balance this with enabling innovation by disruptive technologies and open source platforms – start by considering the revision of stifling legacy regulations.

Prepare for the new competitive landscape

Compared to traditional manufacturing, significantly lower production volumes will be necessary to operate efficiently. Capital expense requirements will decrease. The elimination of what were previously barriers to entry for new competitors means that the Electronics industry will become less concentrated geographically. As a larger number of smaller-size competitors emerge around the globe, Electronics companies seeking to improve their competitive advantage can:

- ***Analyze and specify the optimal scale of production for your business.*** Use modeling tools to evaluate alternatives since large-scale requirements of the past may no longer be inhibitors. Develop scenarios to study the impact of adjustments to your production plans at various points in the future.
- ***Identify necessary internal reorganization and preparation.*** Evaluate and address workforce needs related to competing against smaller, local manufacturing enterprises. Make plans to develop or acquire critical skills when and where you need them, given the new competitive landscape.
- ***Decide where you need a stronger local presence.*** Resize and redistribute industrial infrastructure and investments to support a more distributed industry structure. Understand how the changing industry structure affects your future plans for factory sizes and locations.

Build extraordinary flexibility into your supply chain structure

As supply chains become more "hollowed-out" with fewer tiers, more value will be associated with technology innovation and customer intimacy at the two ends: design and retail. To fully exploit these changes, Electronics companies should focus on simplifying their supply chains and making them as flexible as possible.

- ***Determine which new technologies will disrupt your business, and how.*** Advanced automation, for example, will make manufacturing very flexible in terms of location and upfront costs. Use modeling tools to understand potential impacts on your bill of materials and bill of assembly.

- ***Reconsider the objectives of future technology and plant investments.*** As manufacturing gets disrupted, investments in traditional requirements like modularization and standardization will hold less sway. The selection of a production location will increasingly stem more from regional or local demand than as a factor of labor costs.
- ***Define your optimal position in a new software-defined value chain.*** Today, there is relevance in being a component manufacturer, but that may change over time unless you serve a special niche. Find a role that will remain essential in the ecosystem. Specialized parts like CPUs and LCDs will continue to be made globally while many other parts will be printed and assembled locally – eliminating integration and modular assembly from the value chain.

Self-assessment questions

Electronics companies must grasp the opportunity to prepare for the impact of the three technology revolutions underway in manufacturing. These questions can help to identify useful next steps toward that goal:

- Which of the three technologies will affect your business the most? Which will affect it the soonest?
- How will changing production scale requirements affect your product portfolio? Where are there new opportunities for customization and personalization?
- In what ways can you pinpoint the parts of your business where profits may erode over time due to changes expected from the software-defined supply chain? How can you discover new sources of manufacturing profit?
- Where, when and how will it make the most sense for you to invest in newer technology and future plant locations?
- What can you do to understand the changes needed in workforce skills as a result of the new competitive environment?

Dealing with unprecedented upheaval

Our research confirms that the Electronics industry must prepare now for massive transformation of the industry structure and global trade flows. Unlike the mostly incremental changes of recent decades, this step-change – already underway – is unprecedented for manufacturing.

Enterprises that want to stay competitive will need to identify new sources of profit and customize their offerings to new and changing target markets. The reduced scale of production to be competitive will require understanding the new industry structure and rethinking the optimal choice of manufacturing locations. Companies will need to evaluate their value positions in the new software-defined supply chain.

To learn more about this IBM Institute for Business Value study, please contact us at iibv@us.ibm.com. For a full catalog of our research, visit: **ibm.com/**iibv

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