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Manufacturing 20/20

Understanding the manufacturing landscape of the future, and how the ecosystem, production processes, and business models will evolve.

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Manufacturing 20/20 is part of Castrol innoVentures work to identify potential investment areas beyond lubricants, and included here in Clareo's Future Series, where we explore fundamental future shifts through collaborative Insight Programs[1] that join together perspectives from within and outside an industry to depict potential futures and drive implications to industry players.

Introduction

Manufacturing is at a crossroads today, with significant uncertainty in how its future will play out. Understanding these uncertainties and potential futures is not only vital to companies that participate in the manufacturing ecosystem, but also to the development of nations and the overall world economy. Key uncertainties include the evolution of manufacturing in mature economies, the role that design plays, impact of technology advancement, and most importantly, the impact to manufacturing from growing environmental consciousness.

This paper examines the manufacturing landscape in 2025 and beyond from four perspectives: disruptive production processes, availability of new materials, shifts in the supply chain, and the road to a zero carbon footprint future. We describe potential futures in each of these four areas, and identify impacts to the industry at three different levels—the manufacturing ecosystem, the plant and production processes and business models.

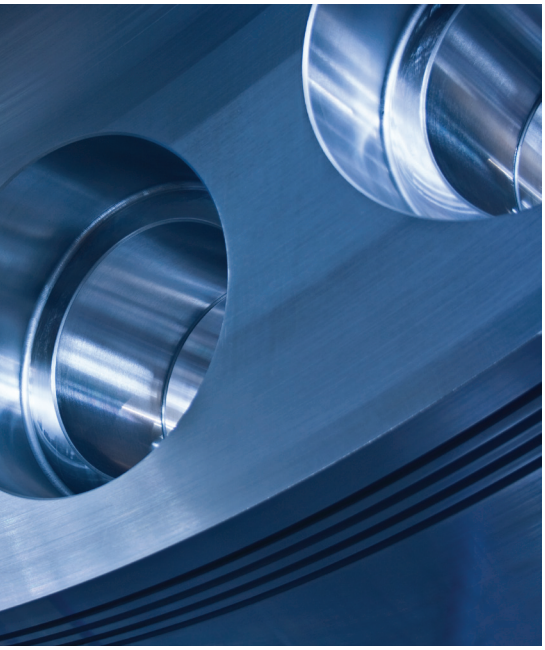
[1] Clareo's Insight Programs: Clareo has developed Insight Programs as a unique way of injecting insights and external viewpoints into our client's strategy development process. They bring together a diverse group of external experts, many from outside the industry, together with our client's executives and key stakeholders to explore a central theme of interest. This Manufacturing 20/20 paper is the result of one such cross industry collaboration.

Executive Summary

Seamless digital design to manufacture results in value shift from manufacturing to design.

MANUFACTURING: Physical to Virtual

Smart manufacturing utilizes advancements in digital technology to disrupt how products are designed, manufactured, and distributed. It places design at the forefront of this revolution—made possible by global standards and cloud computing.



Rise of Intelligent Manufacturing

Future intelligent manufacturing systems will provide real-time, uninterrupted, routine operations that integrate customer demands into the development cycle from specification to product. This is enabled by technology advancements in robotics, sensors, vision integration, end effectors, interoperability on the plant floor and supplier network standards. Use of physical tools gives way to the virtual.

Seamless Digital Design to Manufacture Results in Value Shift

A common design specification language enables separation of design from manufacturing. Cloud computing enables the seamless integration of physically separated design and manufacturing. Open design and innovation rules, with designers seeking inspiration from art, nature, history, fashion, and architecture as knowledge transfers from one domain to the other. Digital 3D modeling (foreground) to finished part (background) is enabled in one step.

Design for Disassembly

Products are designed for disassembly; they are modular and designed for end of life. Software is the key enabler. Certain sectors of manufacturing become distributed with localized production and assembly, resulting in a fragmentation of manufacturers and suppliers playing a bigger role. Manufacturers develop floors for flexible design and re-configurability with minimum of time and cost to enable full utilization of assets.

New Production Processes

Use of additive and direct digital manufacturing grows significantly, as the advancement of metals, plastics, composites, and ceramics using these techniques are developed and their performance envelopes are better understood. These new production processes also enhance the use of hybrid materials and integrated functional parts, with ceramics and metals both playing key roles. The "buy-to-fly" ratio is improved as a result of such new production processes, among others, resulting in waste reduction for raw materials. The sustainability agenda impacts all aspects of manufacturing—from reducing waste to seeking alternative materials and supply chains.

Executive Summary

The sustainability agenda impacts all aspects of manufacturing—from reducing waste to seeking alternative materials and supply chains.

New Materials—Substitution and Opportunity

New materials come in the form of new fuels, use of ceramics in cylinder sleeves, wall coatings, and in rotary engines and advanced composite materials from reinforcement fiber and resins. Composites are widely used, starting with airframes in aerospace and moving to the next frontier—the passenger car. Multiple materials are integrated and combined to create a level beyond what we see today as composite structures. This is enabled by new processes for building the composites, but even more so by new techniques for chemically bonding components together which completely obsolete the need for mechanical fastening.

Designer Materials

Materials are designed for specific environments and applications. New elements are created that add to Mendeleev's classic table, resulting in an expanded periodic table. Further, through new computing capability, new designer materials can be created that fit the component or product—as opposed to the product being designed around the available materials. Manufacturing and material barriers to entry are reduced due to simulation and speed in conception of new materials enabled by the ready availability of massive computing power via the cloud. Nanotechnology is not only about making new materials, but also about improving methodologies by which we develop, texture and combine materials.

Modularization of Supply Chains

The supply chain undergoes fragmentation for strategic reasons such as hedging. It is transformed into a supply web, from a supply chain, as new centers of demand and supply rise in emerging markets. There is a closer integration with suppliers and clear total cost of ownership recognition regarding trade-offs between higher production costs and speed/responsiveness. The role of OEMs becomes one of specialization and system integration. Mass/late customization is widely adopted.

The Sustainability Agenda

Gas guzzlers become as socially unacceptable as cigarettes. Regulation leads this change, but consumer demand accelerates its adoption. Global engine emission standards are tougher—converging to zero—and emissions become as important a metric as quality. Low volume local production will see a renaissance by 2018. The constraints drive the sustainability agenda, with consumers accepting 'good enough' product. The 80-60 rule impacts the supply chain—80% of goods are sourced within 60 miles of where you live. Consumers and manufacturers mine waste instead of taking it away.

Resource Constraints

Resource constraints lead to innovation in materials, products and business models. Product afterlife is very important and deconstruction is adopted. Innovation is focused on the frugal and driven by Brazil, India and China.

SUSTAINABILITY AGENDA: The "Good Enough" Rule

Gas guzzlers become as socially unacceptable as cigarettes. Regulation, consumer demand, and resource constraints drive the sustainability agenda. Consumers accept 'good enough' products, and the 80-60 rule impacts the supply chain: 80% of goods are sourced within 60 miles of where you live.

Disruptive Production Processes

Design capability and integration with the production floor allows made-to-order custom specifications and an Economic Order Quantity of 1 is realized.

Impact to the Manufacturing Ecosystem

Exploding population and increasing wealth, especially in emerging nations, will create significant demand for manufactured goods, indicating a bright future for the manufacturing industry.

However, the future is likely to see regional disparities with China and India capturing a disproportionate share of the new manufacturing economy. The manufacturing value chain will also be de-integrated, driven by design/manufacturing separation and the need for non-linear supply web which increases security to deliver. Globally accepted design standards and cloud computing are the primary enablers of the resulting transition of value from manufacturing to design.

This enables small and medium sized companies to gain share; distributed/local manufacturers assemble for local use and transport. In the sectors where manufacturing fragmentation takes hold, the role of the OEM changes to that of a specifier.

Impact to the Manufacturing Plant & Production Processes

Future production processes take advantage of the growth of disruptive technologies such as additive manufacturing (e.g. 3D printing) and new materials.

Design capability and integration with the flexible production floor allows made-to-order on custom specifications and an EOQ of 1 is realized without the traditional cost and complexity implications.

Digital 3D modeling techniques are a key enabler to the additive layer and other new flexible manufacturing process as the design to build language standards have been established.

The factory of the future will be reconfigurable with flexible tooling and a flexible design floor to accommodate different processes.

There will be increased automation with more robotics and IT on the floor. This lowers the demand for labor but shifts the requirements to high skill and training.

The move to modularization also impacts machinery that is smaller, lighter and electric.

Maintenance will be marked by the use of predictive technologies and diagnostics; maintenance of electronic parts will become critical and software will drive differentiation.

Again, computing power enables full understanding of manufacturing variability. This finally enables lights out machining and manufacturing by 2030, as the variability is continually compensated for and corrective actions automated.

Business Model Impacts

The future could see the transition from machinery ownership to manufacturing purchase use.

In many sectors, scale becomes less important—cottage manufacturing is enabled by the growth of cloud computing and design standards, allowing "artisans" to compete effectively with larger companies.

VALUE MIGRATION: From Manufacturing to Design

The manufacturing value chain will be de-integrated, driven by design/manufacturing separation. Globally accepted design standards and cloud computing are the primary enablers of the resulting transition of value from manufacturing to design.

New Materials

The fields of material science and chemistry merge in the quest to design new materials that meet specific application needs.

Impact to the Manufacturing Ecosystem

There is no longer a distinction between materials and chemistry as companies look to drive innovation that combines and develops new materials, from metals, alloys and composites to nanomaterials. The race to innovate is in cracking the code for scaling production of these new materials—and understanding their performance boundaries.

The scarcity of natural materials and the effort to develop sustainable products drives this innovation; both regulations and consumer demand are considered to shape the nature and timing of these innovations. New uses of materials are discovered, and materials are designed to meet specific requirements and applications.

Impact to the Manufacturing Plant and Production Processes

Greenfield to production uses engineered trusses, with machines and robots handling messy, dirty processes; more and more we are designing structures within structures at the base level of structural integrity. Metals still comprise a significant portion of materials in manufacturing, but there is a significant shift in metal usage and process.

The impact of new materials is felt in manufacturing, in areas such as fabricated goods, machinery manufacture, energy and transportation equipment. Ceramics are now used in engines, and composites became mainstream, such as in car exteriors by 2016. New materials are used in building construction, such as ultra-high performance concrete that uses less energy, is light weight, and more economical. While innovation drives new chemistry, health and safety issues act as a counter force with legislation, government and union resistance. There is a convergence of technologies on the production floor, such as print on ceramics.

Business Model Impacts

Repair becomes more difficult, especially in new materials such as composites. This is counter balanced by self-healing applications that use nanomaterials and sensors. Scaling remains a significant issue in the widespread adoption of new materials.

DESIGNER MATERIALS: Specific and Made to Order

The scarcity of natural materials and the effort to develop sustainable products drives this innovation in materials. New uses of materials are discovered, and materials are designed to meet specific requirements and applications. A new periodic table is developed for nanomaterials.

Supply Chain Shifts

Supply chains will proliferate into supply webs as a means of hedging risk, as well as meeting regional and local market needs and regulations.

Impact to the Manufacturing Ecosystem

The supply chain has transformed into a supply web, with new collaborations and new roles for traditional suppliers. The supply web is segmented, determined by business model and sector. There is a proliferation of supply chains and models, as a means of hedging risk, as well as meeting regional and local market needs and regulations. There is involvement, visibility, and control of all tiers in the supply chain, with the OEM becoming the specifier and/or design gatekeeper. Relationships are important and a holistic approach is used, adjusting work more frequently; with the model depending on volume and value.

Extreme manufacturing is achieved by integration with second and third tiers —albeit potentially a virtual integration. Certification of sustainability is an important driver for supply chains looking to differentiate and meet new regulations. Manufacturing in many sectors becomes localized and uses local raw and multifunctional materials, as well as alternative energy sources where available. IT is a key enabler of the supply web.

Impact to the Manufacturing Plant and Processes

Sourcing is increasingly local and regional, and production processes adapt to accommodate. Late customization enables efficient and optimal use of the supply web, allowing manufacturers to gain scale economies as well as to cater to regional/local market needs and regulations at the same time. Recycling and waste reduction within the supply chain is important, and this impacts all aspects of the production floor.

Business Model Impacts

Companies increasingly look to rent vs. buy materials from suppliers. 2011 examples of this include soft drink cans that are rented instead of purchased. Reliability and traceability are important business model drivers from regulation and consumer demand perspectives.

COLLABORATION WEBS:
Fragmented yet synchronized

Supply chains and models proliferate—as a means of hedging risk, as well as meeting local market needs and regulations. IT is an enabler of the supply web that is orchestrated by the OEM. Sustainability certification drives differentiation of supply chains, with renewed emphasis on reducing waste in all aspects.

The Road to Zero

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The drive for zero waste leads to Manufacturing Zero: Accountability for the full product life cycle, and products are therefore designed for disassembly and end of life storage systems for electricity, such as hydrogen fuel systems and ammonia storage.

Impact to the Manufacturing Ecosystem

Sustainability is not only an option in the future, as companies look to sustainability for profit and risk mitigation reasons. The real driver is efficiency and competition for ever more scarce or costly resources.

Legislation such as a carbon and water tax plays a key role but only begins to lead us down the road to zero before consumer and market demands make it a necessity.

Gas guzzlers are viewed to be as socially unacceptable as cigarettes were in 2011. Consumers increasingly prefer "good enough" in many products that result in little to no waste.

Impact to the Manufacturing Plant & Production Processes

Manufacturing Zero is the new mantra, with OEMs accountable for full life cycle responsibility. As a result, products are designed for disassembly and end of life.

Radical paradigm changes are developed in the production process through additive manufacturing and other process advancements. The "buy-to-fly" ratio is improved as a result of such new production processes resulting in a reduction in waste of raw materials.

There is increased use of cogeneration, recycling, and less use of water.

Energy production is localized to reduce transmission losses. Innovation is driven in storage systems for electricity, such as hydrogen fuel systems and ammonia storage.

Business Model Impacts

Pay-for-use is the new business model using whole life cost of products. Contract based systems and products increase in use, with no need to own.

This creates new opportunities to service, fix and maintain production environments.

Waste is the new material, with recycling, reuse and mining of waste becoming important as companies carry away used products.

About Castrol

Castrol is the world's leading specialist provider of lubrication solutions. From people and businesses to products and services, Castrol makes it work better. Operating in 130 countries and employing more than 7,000 people, Castrol develops and manufactures 5,000 premium quality and high performance lubricants for the consumer, commercial, marine, energy, industrial, and aviation markets.

Castrol innoVentures: Castrol innoVentures is a hybrid corporate venturing arm of Castrol utilizing a mixed innovation model; balancing internal projects, external partnership, venture investments and acquisitions to identify, access, accelerate, and build significant new businesses beyond lubricants and fuels.

To find out more about Castrol innoVentures visit: **www.castrolinnoventures.com**

About Clareo Partners

Clareo Partners a strategy consulting firm designed to inspire and achieve transformational growth for enterprising businesses. We develop targeted strategies to drive growth through innovation, expansion in new markets, development & commercialization of new ideas, corporate entrepreneurship, and venturing & licensing.

Poised at the intersection of business, academia, design, science, art and entrepreneurship, we offer access to a global network of distinguished opinion leaders. Through its highly collaborative methodology, Clareo works with clients to deliver breakthrough, innovative thinking, a practical, clear roadmap, and the customized toolset to reach its long term goals.

We light the path. You lead the way.

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