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Chapter 2: On-demand production models and distributed manufacturing using cloud-integrated platforms

2.1. Introduction

Various forms of production can be used to describe the development of consumer and capital goods by converting raw or intermediate materials into finished products. More traditionally, industrial production is performed in bulk and on the same continuous equipment or manual production line. As such, traditional manufacturing is known for the serialization of product offerings for basic needs across the masses. However, despite higher fixed costs associated with their production compared to other production models in volume, flow, and unit, discrete manufacturing activities are supplemented by a diverse mix of customized tools to rehabilitate product offerings in response to fluctuating market demand throughout each industry and company life cycle. Next, as the number of unique products continues to grow unabated, more companies also employ a variable-cost "on-demand" model to support infrastructure at critical functions of their value chains to help control expense ratios in distortive non-durable markets. Increasingly, such flexible-on-demand production capabilities are leveraging the support of information technologies on high performing enterprise systems that allow for lower entry barriers to manufacturing automation, while facilitating collaborative business-to-business activity with respective production-sharing partners across the value chains of their own production networks (Burström et al., 2021; Chopra & Dhingra, 2021; Javaid et al., 2021).

Taking the out-of-box-thinking of these industry systems a step farther, the new wave of cloud-integrated systems is now allowing many custom encoders, such as manufacturers, to even localize outsourced operations by transferring "intelligent" activities overseas to other specialized, underutilized "on-demand" service providers within the value chains of their own manufacturing networks, oftentimes only millimeters away, who mitigate travel cost and time, reduce production lead times, minimize product pressures, while allowing for even more customized or unique product offerings that require rapid response manufacturing capabilities by small local players. This chapter investigates the potential application of theoretical models of demand for such on-demand production and manufacturing activities to the development of on-demand production and distributed manufacturing capabilities (Sarubbo et al., 2022; Vargas et al., 2022).

2.2. Background and Motivation

The current global pattern of consumption is heavily driven by desires for co-creation and customization of products and services. This unique characteristic of demand has led to the emergence of work in the domain of mass customization of products, offering both a hybrid of mass production and custom production stages. However, mass customization or enclosing the production cycle in very small time frames in such a way that the stages of final assembly happen very close in time and location to the customer are usually very costly activities. On demand purchase guarantees run counter to the incentive to order stocks a season or two in advance. Some examples of products that have been seen as possible candidates for customization and the use of a distributed production model encompass printed t-shirts, postcards and mailers, art posters, greeting cards, mugs, notebooks, shoes, dress shirts and blouses, backpacks, Halloween costumes, furniture, hearing aids and medicine products-rosaries and other products that use machine embroidery.

A growing conviction in the industrial community is that as a result of lowering flexible manufacturing costs, a significant portion of conventional mass production will gradually be displaced by customized production close to home-using local but intensely specialized resource networks linked to the product development process. Such a service link will integrate the entire production chain linking up the customer with product designers and local product assemblers with arbitrarily specialized skills. Such a specialized network could be made to operate on the basis of crawl, walk and run but the necessary enabling infrastructure is not yet in place. Interface hardware and software, communications bandwidth, price quality and performance communications links are the four important areas that need to be developed significantly to facilitate coupled flow models operating on low operating margin products.

2.3. Cloud-Integrated Manufacturing Platforms

Cloud-integrated manufacturing platforms enhance the capabilities of traditional MPSs through increased connectivity, virtualization, and digitization, allowing them to move to another level of performance. These new platforms, although still in early stages of their technological development, already leverage the Cloud and other recent technologies such as the Internet of Things, Industrial Internet of Things, and Cyber-Physical Systems.

Fig 1 : Cloud-Integrated Manufacturing Platforms

Cloud computing provides the infrastructure that enables the collection and resourceful storage of stream data, coming from instruments such as sensors and machinery embedded with IoT, IIoT, and CPS technologies. Cloud-computing services, such as Storage-as-a-Service, Power-as-a-Service, Network-as-a-Service, Brain-as-a-Service, Platform-as-a-Service, Software-as-a-Service, and Thing-as-a-Service enable any company to seamlessly and dynamically offload MPS functions previously performed internally.

A manufacturing platform connects people, processes, and technologies to produce a product. Hierarchical, centralized, in-house focused MPSs are still the most prevalent in traditional mass manufacturing, organizing, scheduling and governing all the manufacturing-related functions in a company. Numerous MPSs exist today, including the Enterprise Resource Planning, Manufacturing Execution Systems, Product Lifecycle Management, Design for Manufacturing and Assembly, and Design for Supply Chain.

All of these MPSs are software solutions implemented for internal use by a single enterprise and with different Departmental or cross-departmental scopes. Solutions that encompass cross-company functions for collaborative manufacturers, called Collaborative Manufacturing Platforms, are still lacking in capability and with limited adoption. Emerging Cloud-integrated MPSs are beginning to fill this gap, enabling surrogate, PaaS, and SaaS MPSs that leverage the Cloud features of always-on, always-connected, data- and resource-rich, and low-cost Cloud resource availability, providing businesses with unprecedented capabilities to dynamically adapt manufacturing resources to changing market needs.

2.3.1. Overview of Cloud Computing in Manufacturing

The global economy requires manufacturers to be flexible and responsive in increasingly complex business environments. Manufacturing operations typically consist of numerous interconnected processes, which if properly coordinated, allow for the efficient creation of products using shared tools and resources. Information technology has traditionally been used to facilitate decision-making and the smooth flow of data throughout the manufacturing enterprise. Cloud computing provides an opportunity to enhance the evolution of traditional enterprise computing environments. Cloud computing is defined as a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources, such as networks, servers, storage, applications, and services that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model is composed of five essential characteristics, three deployment models, and four service models.

Manufacturers have long relied on specialized computing resources to efficiently run manufacturing simulations. These simulations utilize complex algorithms to model scenarios in areas such as logistics, scheduling, system integrity, or throughput. These simulations can determine the most efficient number of parts to be manufactured considering tool lifetime as well as manufacturing and assembly scheduling constraints. These examples illustrate how cloud technology can enable greater flexibility and agility in specialized processing within manufacturing environments. Other aspects of cloud computing may allow or facilitate manufacturing simulation tools being seamlessly integrated into enterprise networks. The collaborative aspect of a cloud-based service is important. A major benefit of cloud computing is to allow mobile consumers of cloud services with disparate backgrounds and skillsets to seamlessly work in collaboration on projects. Because cloud tools are able to provide a global view, users can ensure that everyone is on the same page.

2.3.2. Benefits of Cloud Integration

The past two decades have witnessed a meteoric rise in cloud computing. Many organizations, from gargantuan service providers to small workshops, have embraced the numerous benefits of cloud integration in their IT infrastructures. Compared to traditional centralized server-based infrastructures that can be prohibitively expensive and inefficient, and exclusive local workstation-centric configurations that offer only remote access to isolated nodes, a cloud-integrated architecture provides seamless access to various capabilities, offers a flexible configuration, and enables collective usage of geographically-distributed resources.

There are several advanced capabilities unlocked by cloud integration. Firstly, cloud computing allows instantaneous on-demand access to a virtually unlimited pool of computation resources, which enables just-in-time processing of computational bursts. This bursty nature is often highlighted in manufacturing applications, which undergo extremely high variations in computation loads. Unlike in traditional paradigms, companies can easily outsource computation-intensive and occasionally operational tasks to remote cloud service providers instead of investing in expensive computation capabilities exclusively held in-house. Another unique feature of cloud-enabled applications is that their monitoring and management can be centralized in a remote cloud space. As a result, there is less demand for local intelligent devices at the fabrication sites. The cloud also offers social-network-like functionalities that allow monitoring information to be shared among collaborating sites. Companies can approach cloud service providers to access complex cyber-manufacturing services, such as intelligent system monitoring to detect abnormal machine operating patterns, via the cloud infrastructure without domain expertise in all monitored manufacturing entities.

2.3.3. Challenges in Cloud-Integrated Systems

Although cloud computing certainly has its advantages, the use of cloud for manufacturing has many drawbacks. Security is one of them. For machine tools and processes associated with manufacturing, such as CNC programs, pre-processed CAD data, machine settings and configurations, etc., security is a serious issue if such data is stored off-site, especially in cloud servers subject to attack from malicious entities. Several proprietary methods exist to protect such data against unauthorized access, but these methods sacrifice speed for security. Computationally intensive encryption and authentication which involve encryption of the data, transmission of the data to the cloud, authentication by the cloud, and then encryption by the client, consume cycles and are not feasible depending on the type of the data, but are still the best methods for highly confidential data. Moreover, the cloud environment should be constantly monitored for unauthorized access, such as from previous session key compromises, and threats. For manufacturing, low-latency access, which is the main advantage of using local servers over cloud servers, makes it possible to send sensor data collected during production to local servers, which can then perform real-time processing based on previously trained models. Cloud-based data processing is usually not able to meet low-latency demands. Moreover, manufacturing tasks are time sensitive and even small delays can result in equipment damage, product quality issues, or other problems. For sensitive tasks, local servers should be capable of performing rapid processing tasks, which would offload heavy processing from the cloud. In addition, data privacy is a serious matter in many cases and is related to security. Since cloud servers typically have superior storage space compared to traditional servers, they are used extensively for data storage. However, these servers risk exposing sensitive information of the users.

2.4. On-Demand Production Models

On-demand production models enable manufacturing activities to be focused around the needs of discrete customer orders. This offers contrast against more traditional mass production methods that manufacture parts and goods to stock. Manufacturing-to-stock allows adjustments to be made for seasonality or forecasted demand, but production is not triggered directly by customer demand. Mass customization methods, which have grown in application since the mid-1990s, also offer elements of on-demand production models. While mass customization allows manufacturing systems to feature a high degree of product mix flexibility, orders for goods are usually fulfilled from stock rather than produced following receipt of customer order. The less flexible ready-to-ship inventories are flagged by the customer as optioned products. The on-demand production models, by comparison, make extensive use of build-to-order strategies, regardless of whether goods are simple, complex or composite configurations.

On-demand production models are particularly applicable to complex product goods associated with niche markets. These markets may operate for limited periods of time or engage less frequently with target customers. The latter may await some new innovation, or experience unstable demand, such as that found for computer games, new product introductions in the apparel industry, prints and investments in ceramics, electronics and jewelry. Goods production follows the customer lifecycle, with designs traveling through the supply chain from customer-through-designer-through-supply-chain-partners. The increasing use of product solution packages has also raised customer expectations to include the provision of additional goods or services into the mix when offering goods for sale. The choice of which modes to activate are decided through which solutions the customer selects from at that point in time.

2.4.1. Definition and Characteristics

On-demand production could be also described with various terms in current literature such as: "just-in-time manufacturing" which was originally developed to minimize production waste in mass production; "on-demand production," or "on-demand manufacturing" which refers to client-oriented lean production; "mass customization" which emphasizes on the large-scale distribution and a high-variable production volume; etc. All these terms share the similar notion of creating end-products when the client orders them or high-spec variants over the whole product lifecycle. However, just-in-time production is a restricted version used in product shortening of the production cycle time by reducing work-in-progress inventory levels. Mass customization needs special industrial setups and groups of products with high relevant demands. These three methods are not suitable for low-volume, variable-job-change products for which expensive upfront tooling and equipment costs are impedances to adopting them. In the recent development, on-demand production is specified as a new paradigm shift of manufacturing direction, which ensures making mass value-added changes or lasting improvements to products in low-volume and high-willingness-to-pay market sectors driven by customer direct orders and high-technology. The usage of digital technologies enables to invoke real-time information on consumer preferences or to empower virtual business models, including transactions, for the capital-intense investments in addition to utilizing lean production principles.

Considering all into account, new definitions or characteristics of on-demand production and its players, as well as on-demand production environments in terms of capabilities and functions compared to traditional production in general and exemplifying smart on-demand factories in particular were established. The focus of all these definitions is on both information-based real-time order-driven business processes and cost-intensive short-run remanufacturing of spare parts. Indeed, on-demand production manages industrial assets over the whole supply chain from initial creation, operation to life phase management, and outsourced in terms of internet-enabled communication for central and overseas manufacturing.

2.4.2. Comparison with Traditional Manufacturing

In addition, we also have to point out that, as far as we know, there is no formal definition of on-demand production. Actually, the term is often used in different contexts without any clear definition or only with soft comparative criteria, according to which it would somehow be similar to mass customization or small batch production, but different from both. Curiously, non-academic sites and blogs dealing with applications of on-demand production capabilities use to refer to the latter by means of the thin characterization "3D printing", with no further consideration.

By carefully analyzing these sites and blogs, it appears that those companies dealing with on-demand production through 3D printing are either specialized in the development and delivery of parts by means of that technology, or have integrated that production capability within their regular activities. In both cases, the market scope of those companies doesn't seem to be local with reference to either the supply or the demand side of the business. Rather, their businesses are apparently focused on transactions involving industrially manufactured products that satisfy niche needs for either the characteristics of the product, the timing of the requirement or the geographical scope of that transaction. To put it in academic terms, on-demand production through 3D printing seems to be economies of scope-enabled within a focus/niche business selection.

The fundamental similarity of on-demand production with traditional batch production lies in the way in which the production is scheduled, namely upon the placement of an actual customer order. The only difference is that in on-demand production, the production action responds to customer needs instead of being undertaken as the first action in a generic process leading to the advance preparation of stocks. Rather than the scheduling timing of production, what distinguishes on-demand production is the way in which production is undertaken.

2.4.3. Case Studies of On-Demand Production

Here we describe two examples of on-demand production using distributed manufacturing based on cloud platforms. Both examples are business ventures using off-the-shelf and patented technology. They provide on-demand manufacturing for several degrees of generality, product verticality, and customizability, but focus on consumers rather than industrial services. The first business model responds to a single or low frequency of customer orders, while the second business model is positioned at the edge of mass-customization, catering to local participants.

Tear it Up Inc. provides trendy custom yet designer made footwear, available to customers on demand via the Internet. Each product is manufactured using 3D Printing Technology. The orders are received and processed and are transferred electronically to a partner store, where the 3D design is grouped with templates based on actual color schemes. They are called Capps. After an order is placed and paid, Tear it Up, Inc. adds notes to files with 3D shoes design templates detailing the necessary individualized modifications and submits the files directly to a printer to be 3D printed. Within a few hours, the printed shoes are ready for incorporating the rest of components and shipment. Deliveries are performed via a shipping service, and scheduled to customers by 10 to 16 days.

At the opposite spectrum, in 3D printing hybrid business, 3D printing has merged with the traditional business model of a retail operation for finished goods, either operated by the model maker in an on-site location or by one or more wholesalers which collect the product from suppliers and redistribute it to possible buyers. An example of the later and on-demand hybrid activity performed under platform auspices is a participatory model currently being developed by a city. They will support the community by facilitating programs to ensure that local residents, businesses, and organizations have easier and better access to new technologies.

2.5. Distributed Manufacturing Systems

The manufacturing product is increasingly closer to the demand and a dynamically, easily, quickly deployed closed system of elements, devices, machines, components, people, and organizations is needed, using all available resources. Distributed manufacturing systems manage to accomplish these production needs, crossing all three dimensions (spatial, time, and e-business) of the distributed intelligent production triad, introducing high levels of flexibility, adaptability, and responsiveness to unpredictable demand. The wide use of Distributed Artificial Intelligence in manufacturing, where intelligent manufacturing agents continuously monitor supply-demand conditions and act to employ production resources, has made this step possible.

Any distributed manufacturing system is based on four elements: a demand side, a supply side, a communications structure, and some high-level control system. The demand side can be in fact any customer needing a product and wishing to use the services provided by the distributed manufacturing system to manufacture it. The supply side is represented by a set of production nodes connected by a communication structure, which can be the Internet or an Intranet. Finally, the control function can be carried out by intelligent agents, who can be either the suspension agents or the control systems at the dispatching, on-demand production, or flexible manufacturing nodes, but in all cases the layer of a peer-to-peer architecture. While the internal process inside each production node can be hierarchy managed, the global system functions on-dynamic, peer-to-peer mode.

The main advantages, today and in the near future, of a distributed system architecture of the manufacturing process and some capabilities expected are:

1. Virtual enterprise management of the on demand production process.

2. Innovation and easily growing capability to the distributed manufacturing enterprise.

3. Large diversity capability of a mass customization offer.

4. Distributed, financially balanced profitability.

5. Use of advanced techs but with lower risk.

6. Cooperative approach to the research and development.

7. Distributed control capabilities.

8. Collective learning and education opportunities.

2.5.3. Key Technologies Enabling Distribution

The achievement of the distributed organizational model of the above contains enabling technologies which have matured over recent years and seems able to open distribution increasingly. They include Data Technologies/Systems, Network Technologies/Services, Internet of Things, 3D Printing/On-Demand Manufacturing Digital Fab, Intelligent Agents, Servers, Markets, and People/Faces. It is clear that advanced system integration, integrating all the above enabling elements, as a truly intelligent distributed manufacturing system, as a system, platform, initiative, is a complementary need.

2.5.1. Concept and Architecture

From whence digital technology has wrapped up concepts of logical autonomy, data has been produced, shared, and transformed in a global network of interconnections. It engenders the concept of the Digital Economy, in which Value Creation Retreats to its most advantageous Export Instance: Market Demand. Global Economy Parameterization develops a new development axis, focussing on the design and implementation of On-Demand Production Models of Products and Services. The Distributed Network of specialized, pooled production facilities becomes the Manufacturer’s and the Consumer’s Agency, an Harmonizing System of Locally Managed Production Interactions. In this new perspective, direct virtue with the Demand is the relevant competitive factor, in terms of Value to Cost Ratio, for both Large Manufacturers and Distributed Firms. Large Utilitarian Manufacturing Firms develop Strategies of Market Colonization via sophisticated, specialized High-Volume Production Units, flexible enough to cover nth degree of standardization. Distributed Manufacturing is a non-consuming comparative advantage, a competitive entry made up of local firms capable of understanding Consumer Requirements and managing localized, diversified productive Process Interactions. Small, Localized Manufacturing Firms tend to developing Market Areas in account of Product Differentiation Capabilities, and are then prone to cooperating among each other as Dealers. Product

Development covers Management, Design and Prototype Phases, primarily managed by the Small Manufacturing Firms, and Mass Production by Non-Localized Units.

2.5.2. Advantages of Distributed Systems

When compared to a centralized facility that services a large area, distributed systems can provide reduced delay and lead-time, quicker response time, reduced transportation costs, and ensure that the service meets local market demand requirements more closely, including the ability to customize products or services directly for local markets. In product manufacturing applications, distributed systems can relieve the burden on limited capacity but expensive centralized facilities, allowing those facilities to concentrate on peak demand periods, or on higher technology-level product lines; the lower cost, lower technology level products can be manufactured in many smaller distributed facilities that operate continuously. In service applications, where the service locations may wish to utilize different processes for providing a similar service, distributed systems allow for the flexibility to differentiate processes and services across service locations, as well as the operational autonomy of local facilities to make decisions about operations, services, and prices that best meet the needs of the local market. Furthermore, lower cost and lower technology services can be applied on a continuous basis at many distributed locations, relieving the burden on centralized locations in high demand periods.

Environmental concerns are supporting the concept of shorter logistical loops. A well-designed network of many decentralized capable distributed subcenters, with shared common resources to provide some economy of scale, may be able to provide inventory support to local market demand more effectively in terms of transportation cost and time while permitting faster response to local demand variability. With the continuing increase in the available access to and use of inexpensive computer and automated communications technologies, new business structures and protocols that were not feasible because of transitional delays, potential for abuse, and relatively high transaction costs can now be made operational with an architecture focused on distributed systems. Thus, as communication technology improves, the comparative advantages of decentralized decision making may shift further in favor of local business autonomy.

2.5.3. Key Technologies Enabling Distribution

In today's world, increasing emphasis is placed on technologies that are distributed in development and manufacturing. Traditional production models are becoming outdated, and existing barriers to outsourcing are collapsing. A number of emerging information and communication technologies are converging to make these disruptions possible, as well as opening up new possibilities for the management of marketing, design, production, distribution, and other business activities in general. Examples are cloud computing; open and integrated platform development; micro, mobile, and wireless distant communication networks; service-oriented and web-based software architectures; virtual teams and ubiquitous working environments; advanced physical and virtual infrastructures; and a host of others. Such cloud-integrated platforms that allow for distributed, on-demand production have several benefits. Cloud computing technology can indeed support distributed, on-demand production of products via cloud-integrated platforms that utilize external virtual resources and collaborative partners.

The advantages of on-demand production of multiple varieties of products based on consumer preferences create a host of opportunities. For instance, the increase of market demand for personalization at competitive prices is pushing manufacturers to offer mass-customized products instead of mass-produced generalized products. As such, market and design activities have to be conducted much closer to the consumer than in the traditional case, and cloud-integrated platforms are well positioned to facilitate such market interactions. The increasing cost and environmental impacts of traditional manufacturing logistics processes and activities are also driving managers to explore the use of smaller systems for geographically decentralized on-demand production activities. Such activities could result in reduced logistical costs and shorter overall lead-times between decisions and deliveries.

2.6. Integration of On-Demand and Distributed Models

Certainly, given only a limited time frame, implementing and experimenting with one model rather than another can lead to sub-optimal results. There is an obvious learning period and it is even more obvious that during the market penetrations phase, production quantities will be small. These negative aspects have been identified and, in several cases, solved thanks to the integration between on-demand and distributed production. The division of labor between on-demand and distributed production occurs with the first attempting to seize product gifts with high margins, given product characteristics while letting the second produce higher cost incidental products. In other words, the optics of on-demand production are at the mass customization level, while of distributed production the optics are at the more general level of the large number of products for the domestic market. In other situations, one model works as a back-up of the other, and the basic concept is that the on-demand model is able to meet both planned and unplanned need for custom parts along the supply pipeline. The on-demand model is therefore seen as enabling more localized production enabling distributors to offer their customers minimum response times for less vulnerable parts.

Again, an inherent synergy exists between the on-demand and the distributed models. It should not be expected that one model will eventually dominate – rather that both will coexist, fulfilling different needs. In numerous other cases, for example, namely for some custom models of the most important motorbike producer at the present time, the logic is much closer to that of distributed production. The components are manufactured at a local level, getting printed chicks that comply with a standard specification, using the on-demand model. In any case, the boundary between the two models is very fluent: What will specify presented is really a hybrid model, integrating elements of both the on-demand and the distributed production model. More specifically, let refer to it as hybrid production, and view it as providing the advantages of both the on-demand and the distributed production model.

2.6.1. Synergies Between Models

In particular, on-demand production models, as characterized with small batch quantities, have limited production capacity and throughput. Additionally, their core strength is in product variety, complexity, and rapid response – not scale, by leveraging advanced digital capabilities. Constraining on-demand manufacturing to a traditional central factory with optimized economies of scale limits these attributes. Shrinking central factory capacities relative to global demand is a root cause of increasing leadtimes. On the other hand, distributed production models driven by localized demand have production capabilities that scale up and down relative to fluctuating volumes. Because they are distributed geographically, with small yet optimized capabilities in localized markets, such soft bottleneck capabilities remove the leadtime impact from localized surge demands. The result is simultaneously enhanced service at lower cost. Thus, by deconstructing the supply chain for a particular product or product family using an appropriate configuration considering variety, scalability, service, cost, and use of digital capabilities, companies can establish a hybridized offering that optimally configures core model advantages to achieve superior market capabilities.

Many lower volume but highly complex products that are centrally manufactured require substantial customer enablement in terms of cabin or vehicle configuration, and waiting for two months to two years for delivery. This “pain” of long leadtimes is tolerable because of minimal alternative product offerings. With the innovative use of digital technologies for visualization and engineering, and the creation of distributed visible-on-demand manufacturing networks for vehicles, the promise of pain alleviation can be achieved. The synergy of the two models facilitates superior consumer enablement, and rapid localized production to create a true luxury product that is differentiated from available alternatives both for attraction and acquisition.

2.6.2. Real-World Applications

3D Printed Maps, a printing services business, provides insight into how this integrated model works in practice. Founded by a former first response officer who saw great potential in 3D printed maps, and is being used in poor urban neighborhoods suffering from violent crime, the company provides first responders and disaster relief organizations with the types of custom designed printed solutions not readily available through commercial printing houses. By utilizing the centralized on-demand model, Maps can rapidly deliver customized products in situations where access to large commercial printing machines is difficult. Maps uses the distributed model in that officers can employ a small 3D desktop printer that is located in either a department office or even their own home. The small printer, combined with a proprietary digital material library, can deliver a useful product within hours. Libraries of 3D printed maps of different cities are stored and made available for printing on demand. Since Maps partner with dozens of volunteer US police departments, the cost is only a few dollars more than the small desktop printer cost, making this tool feasible for departments not able to purchase several thousand dollar printers.

Letsconfly, a small scale producer company founded by a traditional model hobbyist, offers the template for yet another integrated model. The founder at Letsconfly makes use of the centralized on-demand printing model. The specialty airplane kits like those of Letsconfly can be done in the distributed production environment, with orders placed by hobbyists in remote locations whenever they like the overhead cost for the small scale model kit. They make it compelling even at very small scale and help create value. The Letsconfly model also showcases how integrated arterial innovation can provide the population. It could inspire additional at-home and at-office innovation by designers and producers. This focuses on inspired creativity in pop culture, particularly in an era where the hobby slow minute geek has monopolized before.

2.6.3. Impact on Supply Chain Management

Currently, the supply chain paradigm has included new methods and newly understood architectures. For example, the concept of distribution and sharing of information from the first stage of product design. On the other side, there are actors that make each of the stages of the process happen in the numbers and volume prior to the product demand, from design to production stage consideration, through the various possible processes and distribution of the goods. Also, the demand side of the supply chain is getting much more complex, with consumers that long for customized products. In this stage, we are talking about individual need market. This, in the simplest analysis, could be easily satisfied with a few suppliers around the world and each able to make everything for everyone.

Clearly, such projects are extremely complicated and only a few manufacturers have the tools to support global operations. Also, the mass product strategy still works, featuring the long-gone holder of the world's economy. Companies starting to develop the on-demand mass production models around the globe need to take all this recent evolution into account in order to make successful the proposed model of near-completion customized products. In this direction, a new way of connecting these model and company operations would be via cloud-based platforms, providing a marketplace for services, all throughout the product's life cycle. In such a new paradigm type, individuals or enterprises would outsource any of their product life cycle steps tied to industrial services. These services could be anything related to product design and development or any process of the logistics loop tied to mass production or mass customization. Under the cloud's umbrella, companies could explore any of their product phases with specialized companies or individuals from all corners of the world.

2.7. Technological Innovations

The Fourth Industrial Revolution is characterized, among other aspects, by the revolution of production technologies, a process that is on the verge of unlocking automation and digitalization in domains of life and types of business that have not been subjected to them so far. These changes are manifested in many ways, such as in the immersion of machine-tools in the Internet of Things that are able to communicate with the users or co-produce the products with him over the whole life cycle of the product; in the birth of ultra-high-speed manufacturing via ultra-short laser pulses; in the introduction of soft automation and integrated environments in assembly systems; in the self-manufacturing and self-test of precision functional components and the introduction of metamaterials into semiconductor devices, making it possible to create so-called photonic crystals – integrated circuits with astonishing data processing and communication qualities. Additive manufacturing, smart manufacturing environments or Cyber-Physical Systems, and Artificial Intelligence in production are some of the aspects involved in this profound change.

In the particular domain of product fabrication, the technology with the greatest impact will be Additive Manufacturing. Additive Manufacturing provides designers with remarkable creative freedom, removing the limits posed by topological optimization and capacity constraints imposed on traditional machining technologies. However, it always has the required quality for demanding products and by its properties possible to create products and components with non-standard properties, for specific applications. Because systems design will never substitute traditional technologies but complement them.

2.7.1. Additive Manufacturing Techniques

Additive manufacturing (AM), commonly referred to as 3D printing, is a transformative approach which promises to enable more agile and localized production and will radically change long-established business models.

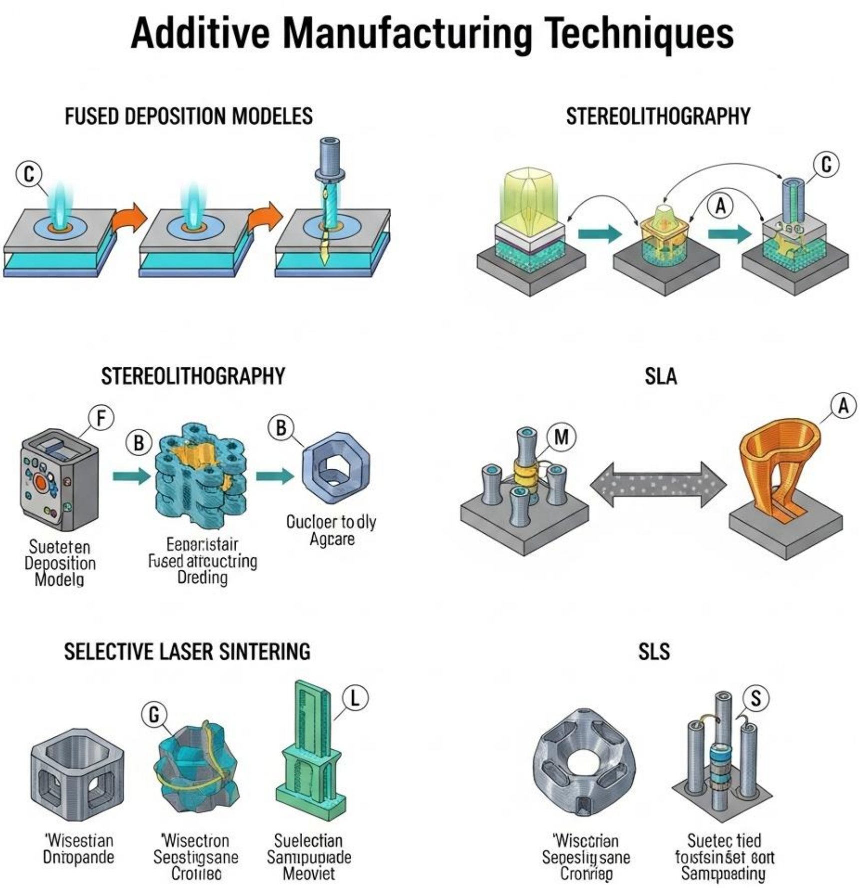

Fig 2 : Additive Manufacturing Techniques

AM techniques generate products by layer-by-layer addition of materials, and allow high design freedom with low production preparation costs – although production cost and time for low-cost systems remain high when it comes to serial production of large product quantities. Many different AM processes and technologies have been invented or brought to the level of industrial implementation, ranging from paper, polymers, metals, ceramics, rubber, and composites, with service capacities ranging from prototype production up to the level of industrial use for sensitive certification-dependent and high-value metals parts.

Described as “the titular technology of the Fourth Industrial Revolution”, it appears likely that AM will be applicable to a broad variety of problems and real-world scenarios across industries, including creating and supply of spare parts for maintenance, repair and overhaul operations that are not economically feasible or viable using traditional mass production and holding stocks of large physical inventories; press-forming tooling of low volumes that do not justify high costs incurred by traditional press-forming tooling solutions; to create customer-configurable and personalized products that will always remain as single pieces or very-low-volume parts of metal and polymer; product prototypes using metal polymers and sand base solutions for incorporating internal geometries and structures. Such a capability would also enable incorporation of lattice internal structures in situations where optimizing weight would drive product design. If certified and used responsibly, AM may also out-protect the weapons of increasing lethality that are made possible by advanced robotics, artificial intelligence, and increasing miniaturization.

2.7.2. IoT and Smart Manufacturing

The Fourth Industrial Revolution is based on technological innovations such as additive and subtractive advanced manufacturing processes, Internet of Things devices, and robotic systems integrated with powerful data processing capabilities based on Artificial Intelligence and big data analytics coupled with inexpensive data storage. These systems are utilized for smart manufacturing and integrate on-demand production planning systems enabled by Cloud computing. The implementation of the Internet of Things in critical infrastructures such as manufacturing enables the distributed management of objects, equipment, and systems from any place in the world. This increases productivity by enabling faster, improved decision-making and enables production systems and infrastructures to autonomously manage unforeseen contingencies such as unexpected breakdowns by coordinating the spare part and/or subcomponent supply chain. This system will reduce the need to warehouse supplies and components for contingencies since the equipment with IoT devices will be able to automatically estimate their remaining useful life and be able to manage their replenishment close to the time when they will be needed.

The coordinated management of manufacturing ecosystems will optimize their utilization. It will also contribute to reducing their carbon footprints, the carbon footprints of their final products, and production delays. This is why large corporations are investing heavily in the development of IoT devices, systems, and services. Sensors attached to all kinds of multi-domain objects such as people, vehicles, satellites, and buildings, and actuators enable monitoring of many variables, and make events like the distribution of people in cities and forecast of city traffic jams, real-time management of the logistics of goods, and management of structural health of bridges. However, more work is needed to cost-effectively implement IoT devices and systems for small and medium-sized manufacturers.

2.7.3. Artificial Intelligence in Production

Progress made in sensor technology, machine learning, image processing, and distributed computing over the last 30 years has contributed to the emergence of computer intelligence, which is driving the development of smart cities. Artificial intelligence is gaining importance in the development of industry, services, and manufacture, because of its potential to boost national economies, enhance governments' decision making, improve what service and product producers provide, and maximize what consumers gain from processing cycles. AI is progressively directing the development of 4th industrial revolution with the introduction of novel new AI-based approaches for nearly all manufacturing processes, including Decision Making; Design; Product Development; Control Timely Production; Production Planning; Production Optimization; Quality Control; Customer Support. Several concepts have been proposed to understand Industrial AI, machines that rely on AI but do not collaborate; data/knowledge-enabled machines that enhance manufacturing operations aided by AI; contain AI-based services that receive information to perform other AI-based tasks in manufacturing; or give AI-based support to assist people in taking decision making with AI. Artificial Intelligence is applied in the following areas: Automated Optical Inspection; Robot Vision and Robot Control; Human-Robot Collaboration; Human Emotion Recognition; Predictive Maintenance; Digital Twins; Planning for Smart and Reconfigurable Manufacturing Systems; Reinforcement Learning; AI-Cyber Physical systems; Intelligent Product Design; Industry-Oriented Decision Intelligence; AI-based Intelligent Logistics; Intelligent AI-enabled Factories; Reactive Knowledge for AI-based Smart Manufacturing Systems.

2.8. Economic Implications

Economists and business forecasters have been wrong about the promises of change. Manufacturing is an example of radical change, with on-demand production and distributed manufacturing having ramifications for entire economies in areas such as job creation/loss, capital utilization, and international trade. These new models reduce the lead times and stockouts that plague manufacturers and retailers. On-demand production is not without its challenges, including the costs associated with creating digital inventories, managing capacity, ensuring product quality, and aligning prices across markets. Not every product can be made on demand, which mostly fits low volume and customized items. The economic benefits and implications of on-demand production outweigh its costs and challenges.

An on-demand economy means new opportunities to reshape product supply. The new digital infrastructure lowers and even eliminates the barriers of entry to product manufacturing, thus allowing any entrepreneur a chance to become a fabricator. These changes in digital supply-chain infrastructure and on-demand production are altering the economic fundamentals of product development and distribution. Investors are backing dozens of companies developing on-demand capabilities and associated digital technologies. New products can come to market much faster, even on the same day the idea is conceived. Reduced market lead times can minimize the need to build and store inventory, especially for fashionable items that become popular for a brief period, or items tied to a special event.

2.8.1. Cost Analysis of On-Demand Production

Cost analysis is an essential first step in identifying the economic potential of a new technology, process, or service. In the case of on-demand production, costs will dictate how widely applied and successful the service may be. Large-scale applications have established the current cost levels for both traditional manufacturing and for products that are currently economically feasible as on-demand production services; however, research has not established a generalized cost model nor has it explored the unique cost factors important to varied future applications of on-demand production in loftier microscale or specialty markets or those suitable only for limited run sizes due to overhead costs. This section does not seek to provide such a model, but rather provide examples, guidance, and context for the developers and researchers wishing to create such models.

One of the common claimed benefits of on-demand production systems that employ distributed manufacturing networks is the low costs, either as impossibly low prices or impossibly low profit margins. In extreme identification with local production, the idea has evolved that mass customizing –such a useful strategic tool for both customers and vendors– ought to be free, or nearly so. Empirical examples show this to be far from the case. A closer examination of these examples suggests that the initial promise of disintermediation, and of decentralized market-directed self-funding, has not yet come to maturity; on-demand methods and services are vastly more popular at the largest dimensions of market niches for short run manufacturing. Such applications are mainly streamlined versions of traditional processes, rather than the ingenious systems of self-funding product community support that many made or hoped made it possible.

2.8.2. Market Trends and Forecasts

This section aims to provide an overview of the trends that facilitate and increase the use of on-demand production. The trends are discussed based on three product groups: 1) Market needs: the need for customization and variety, 2) New technologies: technological developments in additive manufacturing, and 3) New logistics: distribution networks and service challenges.

The idea of on-demand customized products on the basis of customer demand being used to respond to changing market needs enables companies to go beyond the traditional modes of online communication with customers and allows for active interaction, co-creation, and communities of interest. Engagement with customers assists in image-building and selling products. Retailers allow customers to post photos of their preferred styles in hopes of attracting a stylist by offering to send such posts to thousands of customers. Indeed, there is a great deal of activity among small companies that produce small lots of customized products for virtually no profit through their specialized websites, using textile network design tools.

Fulfillment of customer orders often involves long lead times due to both transportation time and the order processing time. Computer-aided design and rapid manufacturing are used to shorten order-processing time. Local companies supported by innovative design tools, and relatively fast, on-demand, logistic, and rapid-transportation operations, can fill orders for made-to-order products for customers at remote locations. Key components of the innovative, on-demand, logistics are fast turnaround of order and small quantities of stock, fully integrated with manufacturers using rapid-response protocols and high-capacity stock technologies with investment in stock replenishing products. These component technologies include radio frequency identification and real-time tracking information.

2.8.3. Investment Opportunities

Investment in cloud-based digital production resources is not new. One individual has spent millions trying to get businesses to outsource their prototyping. In fact, this individual might be viewed as the initial cloud broker for 3D printing, offering a web-based order entry platform and access to a network of machines. More recent activity on the cloud production scene is due to improved tools, a growing network of digital fabrication resources, and growing confidence in the future of 3D printing. Traditional brokers such as auction houses and custom shops that bring together buyers and producers might make the first moves. However, the big players will be better positioned to broker these services.

Cloud brokers will spring up, but how they will help businesses find the services they seek is not yet clear. 3D printers are not becoming ubiquitous. Then key questions will be asked as these organizations expand from early implementor service strategies to wider custom services and products strategies. Is an outsourcing strategy feasible? Reviews of the custom services industry will give search engines clues as to which teams can handle the high-value custom production. What are the needs of specialized businesses? How accessible are these customized services? In the near future, brokers will help companies find print service providers within a specified timeframe and at a specified cost. As the market for additive manufacturing continues to develop, construction companies will rely on their supply chains for custom services. Brokers of cloud-based desktop 3D printing services will find their range expertise made deeper.

2.9. Sustainability and Environmental Impact

As production shifts toward greater levels of distributed and on-demand manufacturing, there are growing opportunities to impact the sustainability and environmental impact of the entire global manufacturing system. Improved supply chain practices can reduce overproduction and product transportation distance, make better use of localized resources, and determine demand-synchronized production of custom or semi-custom products. To make good, science-based decisions in these areas, manufacturers need to work with new metrics, often based on the goals of lifecycle assessment tools. Research is still evolving in these areas, determining how to balance economic decisions with the need to consider and prioritize diverse, sometimes-awry sustainability impacts throughout the lifecycle of products. It is also necessary to understand the technology-associated sustainability tradeoffs, since many new technologies can help improve sustainability but also have hidden challenges. This involves addressing key, fundamental product, process, and supply chain strategies associated with environmentally-conscious product design, manufacturing, and distribution, and using advanced intelligent automation, enabling technologies, and distributed production networks to then efficiently carry out these strategies. These are needed to develop manufacturing processes and supply chains that are not only energy and resource efficient but also can implement the production and use of very low impacto distributed production work that uses innovative energy sources.

2.9.1. Eco-Friendly Manufacturing Practices

Sustainable manufacturing minimizes negative effects on the environment and community while conserving energy and natural resources. Sustainable production is a key part of the sustainable product life cycle and lifecycle sustainability. It is associated with life cycle planning, life cycle impact assessment, and goal and scope definition in the life cycle assessment structure.

Life cycle planning is the phase that considers the entire life cycle of the product and its impact over its entire life, from product conception, material mining, processing and manufacturing, product use, and recycling or end-of-life phase. Planning for life cycle impact assessment includes preparing to calculate the impacts the product has on the world during its entire life. The definition of economic and environmental goals and scope includes establishing criteria for the desired environmental and economic sustainability level, which influences the methods used to calculate the entire life impact and the criteria that must be met. A product that is not economically justified will not be produced, and conversely, a positive economic justification could mask the responsibility of the manufacturing process in long-term pollution effects.

The environmental criteria associated with the planned product life cycle usually affect the assembly and combination of components that occur during the production or processing phase. The first part of this section describes the eco-friendly manufacturing and processing practices and technologies that influence decision-making. Sustainable practices in manufacturing include the efficient and sustainable use of energy and water, a reduction or elimination of hazardous materials, and the reduction of carbon dioxide and greenhouse gas emissions and other pollutants.

2.9.2. Life Cycle Assessment of Products

The quest for eco-friendly products and low-impact processing methods are now the two end priorities in product design. Expanded governmental and private research funding and, more recently, the introduction of special reward mechanisms have accelerated the collaborations between the manufacturing and the ecological design communities. Major strategies for achieving reduction of environmental impact in the design of manufacturing processes utilize a combination of life-cycle assessment techniques and methods from the areas of information technology including software tools. These help in data collection, auditing and reporting to meet legislation and other requests for sustainability information. Customary methodologies now typically employed for the fulfillment of eco-design tasks may include the use of decision supporting procedures which is a creative innovative product planning approach guided by environmental objectives and that is focused on different phases of the product life cycle. The manufacturing phase becomes the crucial concern for a high percentage of eco-design tasks because it may be responsible for the longest possible life-cycle time.

Although the tool box available to the design professional is quite diverse, it is still limited and in contrast to a number of reliable design methods supporting conventional design objectives which are available to the designer of new products or processes. Some of these methods are quite powerful and can assist either decisively or in an advisory role throughout the design process. The critical technical and economic nature of the product/process task combination pursued in conventional design is shared to some extent by products whose design is primarily driven by ecological objectives. In addition, there are also strong similarities between eco-design and the desired design of innovative products or the term that has become synonymous with eco-design. The objectives, concerns and issues are also quite similar in both cases. Similar to the product design approach within the broad definition, the approach to eco-design is also based on reducing consumption of raw and energy materials and reducing waste products and atmospheric emissions.

2.9.3. Regulatory Considerations

With the emergence of environmental consciousness, legislative regulation is influenced by society and its members. Today, social responsibility and altruism are important psycho-economic factors. Modern companies are compelled to think not only of their profits, but of their responsibility towards people and nature. Customers wish to be convinced that the merchandise they rule out was made with consideration for nature, humans, and society. Damage to the natural environment, however, is inevitable when production of any type is conducted. The natural environment must possess sufficient capacity to assimilate any waste produced. If it does, the long-run production function can be such that doubling the use of all factors will be associated with less than doubling the amount of output. A restrictive regulation may inhibit growth by preventing something from happening. It is only recently that the relevant authorities began thinking about the content of the regulatory policies they implemented, on the assumption that it was not enough to use regulations just to prevent companies from performing harmful acts.

As far as at least some forms of regulation are concerned, it has been claimed that neither industry nor government has been especially concerned about the industry's environmental responsibility. A company that produces according to the regulations is said simply to be earning a license to operate. The demand for environmental security has led to new markets related to the management of companies that propose environmentally safe pharmaceutical products or environmentally conscious processed food. However, some of these companies may also be trying to take advantage of existing crisis situations.

2.10. Future Trends in Manufacturing

Trends are fluid and lead us in different directions. Some are a result of change propulsion systems, some focus on sustainability and reduction of environmental impact. The last ensures the continuity of future life. As well as manufacturing, in the last century any production effort during economical prosperity, were oriented to increase the speed and volume of production, to reduce the cost of the single piece. Mass production systems followed this strategy and generated a similar architecture of products. These led to new product development that were more about what could be manufactured than about what customers really desired. So any demand fluctuation was multiplied and led to increasing inventory costs. Therefore manufacturing finds today a new wave of change. Modern trends in manufacturing are driven by several powerful transformations related to emerging technologies; the evolving globalization and localization of demand and supply flows; the shifts that are going on in the manufacturing workforce.

Emerging Technologies. New manufacturing technologies will allow: larger varieties of products to be manufactured with much smaller setups; faster flows at much smaller costs; modularization of products to meet functionality, cost, and performance criteria with different customer segments; integration with other phases of production and supply flow. Hereafter, we introduce some of these technologies that alone or more frequently synergistically combined, will change how products are designed and manufactured. Globalization and Localization. Considering the network economy scenario, closed interfaces between the economy of nations disappear. It is no longer just a supply driven economy. The globalization of markets creates a demand driven economy, where the fast learning of cities, regions, nations can create new markets, becoming the wedge sending the economy to the performance goal. This environment is also a consequence of liberalized trade rules that allow conceptually any manufacturer to enter any market.

2.10.1. Emerging Technologies

Many emerging technologies aim to improve traditional manufacturing sectors, bundling products and services under the concept of the "intelligent factory". The evolution of advanced technologies is key if we want to achieve this intelligent factory of the future. This is supported by various reviews available in literature, which state that trends in manufacturing are mainly based on robots, automation, the use of data science, artificial intelligence, industry 4.0, and intelligent sensors. At first glance, some of the features that characterize the intelligent factory are: (i) increases in labor productivity; (ii) more personalized products (mass custom production); (iii) rapid and efficient production; (iv) source of relevant data for the entire supply chain; (v) sustainable from an ecological, social, and economic perspective; (vi) seamless integration of supply, production and delivery; and (vii) a productive activity capable of generating continuous income. All these features lead the market to provide more and better products with better service and at lower costs over a long time. The intelligent factory will also be the result of the development of advanced emerging technologies of robotics and associated technologies, 3D and 4D printing, nanomanufacturing, big data and data science, artificial intelligence and machine-learning technologies, etc. All these features lead the market to provide more and better products with better service and at lower costs over a long time.

2.10.2. Globalization and Localization

An emerging trend in manufacturing is the continuing globalization of markets: cellular phone assembly contracts are being awarded by industry prime contractors to suppliers from a myriad of countries around the world. This is no longer a service that can be provided by leviathans in Asia. The specialized disc drive assembler must have facilities in Brazil for that new product that runs out of a fast-fill facility in Maine. Infrastructure providers are also forming partnerships; a major printer partner formed a joint venture to provide the service of developing an entire supply chain and the service to maintain it.

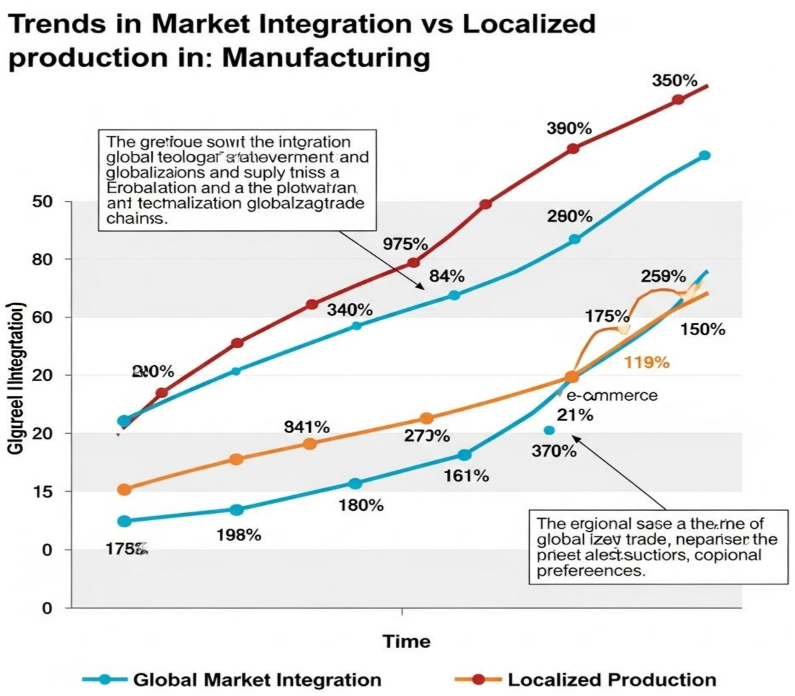

Fig : Globalization and Localization

On another front, localized or distributed manufacturing of those complex products involving many individual product items is growing in the other direction. Factories are becoming increasingly autonomous within the framework for developing the supply chain. This arises from the increasing packaging of the production ability in factories into virtual firms or virtual nations. Heavy-duty machining and painting subassemblies such as chasses no longer need to be collocated with complicated systems with highly variable demand factors. The localized or distributed version of manufacturing has typically been largely limited to production of such clusters involving high component-item to product assembly-item ratios: that may be about to change. New on-demand manufacturing technologies are being developed to meet the different steel and plastic-bodied passenger-car models for the 90s. High-temperature superconductivity manufacturing technology has been proposed to develop the flat-product that would consolidate all of the possible chasses or vehicle machines.

2.10.3. Future Workforce in Manufacturing

People have worked in factories for hundreds of years, starting in the days of cottage manufacturing. The power of machines to greatly amplify human production is easy to understand. Advances in materials, process, and the technologies that support them have transformed production capabilities to levels difficult to imagine a mere century or two ago. Skilled artisans have found their skill set made obsolete by fast, automatic machines. There are fewer and fewer factory jobs that require manual dexterity. We must wonder, what kind of a future do robots, digital manufacturing, and intelligent automation make for people? Will we face the prospect of a future with fewer and fewer jobs in manufacturing?

As companies increase their investment in robotics and digital manufacturing—a trend that is accelerating as a result of the pandemic—and the workforce needed for those jobs decline, society will need to devise solutions to both transition people out of jobs that are no longer necessary, as well as bring people into these skilled, high-paying jobs that remain. What has already begun as a transition toward preparing and employing our future workforce based on competencies, not only formal education degrees, has to accelerate. Educational systems will need to embrace this change, assure access to this new way of training for greater growth, and embed the necessary elements of sustainability, equity, and diversity that critically need to be enhanced for people from underrepresented communities. As social behavioral scientists point out, as the demand for education and skill rises in the labor market, so too does inequality within society.

2.11. Conclusion

On-Demand Production Models and Distributed Manufacturing Using Cloud-Integrated Platforms provides a systematic overview on cloud-integrated distributed production and a descriptive study of dynamic and distributed production to meet market demand in real time. First, to be prepared for those who are not experts in manufacturing, we explain globalized manufacturing, Industry 4.0, in-depth on-demand production models, along with a short introduction on real-time market dynamics. The rules of the game of the forthcoming challenge in productivity dynamics in real time is in and out: interactive relocalization of on-demand production stage in short digital loops to avoid logistical creations. The following chapters illustrate the wider dynamics of the system. Cloud-integrated production systems are a flexible response to market signals. They allow a variety of products and their localization if necessary. This is to be fulfilled when market production demand goes up in less than 5 days at the start or relaunches at high speed of market dynamics. Intelligent production system proposals are considered. Their limit is their capacity in attracting an increasing share of real market dynamics. This trade-off shows the relevance of decision logics associated with production activity. Making the right choice at what stage, location, scale, organization and with what technology - blending traditional technologies with digital innovations- is the guarantee of participating in the share of real demand meta-stability. This last dimension of meta-stability is to get organized at the local level, designing evolutive decision chains to trigger cloud contribution and sharing along the supply-demand chain. It is this self-capitalization of the very structures of production organization that provides roots to the cloud contribution. The enterprise is different, because it stands self-capitalized, able to invest and provide hands-on leadership for getting local-wide synchronized and up to its organizing and process-transformation responsibilities.

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