Chapter 3
Smart Manufacturing Systems Management

George Carutasu and Nicoleta Luminita Carutasu

Abstract The influence of IT in the manufacturing systems became not only visible but also a necessity of operational management. The manufacturing systems evolution is presented using a comparison between the industrial revolutions and Maslow' hierarchy of needs, up-to-date. However, the presented evolution used life quality indicators, to explain the need for continuous adaptation of the manufacturing systems to people, the end customer. The virtualization of the enterprise IT system process and the reference cloud architecture is also presented, in order to clearly estate the prerequisites for Industry 4.0, with a detailed map of the internal cloud processes. The study also presented the major software providers prediction, before and during the COVID pandemic time, which greatly impacted consumer behaviour. Furthermore, the changes of the customer behaviour, cumulated with the globalization limitation, and workforce polarization, affected businesses in terms of rethinking the supply chain, with the target on flexibility, prediction and resilience and the attitude regarding the employees. The conclusions section summarizes the key findings of the study and exposes the authors' prediction for the short-time evolution of the manufacturing systems.

Keywords Manufacturing systems · Industrial revolutions · Organizational management · Cloud computing · Industry 4.0 · Industry 5.0 · Smart manufacturing

---

G. Carutasu (✉)
Romanian-American University, Faculty of Computer Science for Business Management, Bucharest, Romania
e-mail: carutasu.george@profesor.rau.ro

N. L. Carutasu
University Politehnica of Bucharest, Faculty of Industrial Engineering and Robotics, Bucharest, Romania
e-mail: nicoleta.carutasu@upb.ro

A. Draghici and L. Ivascu (eds.), *Sustainability and Innovation in Manufacturing Enterprises*, Advances in Sustainability Science and Technology,
https://doi.org/10.1007/978-981-16-7365-8_3

1 Manufacturing Systems Evolution and Previous Forms of Organization

The evolution of the manufacturing systems and industry, in general, came to a closer comparison with Maslow' human hierarchy of needs [39]. The following figure reflects the reason for comparison, enhancing each need covered by the industrial revolutions.

However, having as a starting point, the First Industrial Revolution, which came in the late eighteenth century, and an ending with a projected state with no human engagement in the production of goods or services, it must be further exploited, using several indicators, like life expectation, income, and gross domestic product (GDP) per capita, whether those evolutions are reflected into people's everyday life (Fig. 1).

Using the data available for the range of late 1700 to today from various sources [48, 54, 66], the industrial revolution impact on the major life quality indicators is presented in Table 1.

With a 40.75 years world average life expectancy, for the period 1778–1889, covering the First Industrial Revolution, the beginning of the era, and from the available data in the UK and Sweden, a starting life expectancy is 35.5 years in Sweden and 37.7 years in the UK. The same countries finished the First Industrial Revolution

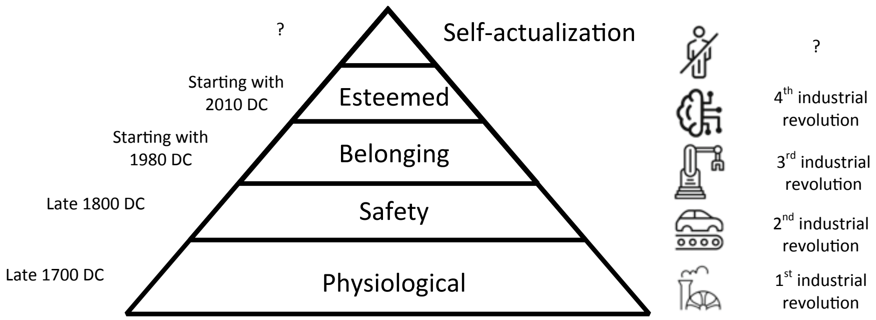

Fig. 1 Close comparison between human need and industrial revolutions

Table 1 Life expectancy versus industrial revolutions

Industrial revolution/time span	Average world life expectancy (year)
First Industrial Revolution (1784–1869)	40.75
Second Industrial Revolution (1870–1969)	53.07
Third Industrial Revolution (1970–2010)	63.42
Fourth Industrial Revolution (2011–present)	71.45

with 45.9 years, in the case of the UK and 52.26 years for Sweden. The impact of the First Industrial Revolution on the health, wealth and population was closely analysed by Buer in [5], appreciating the rising of the population in the London city, based on multiple historical sources for England and Wales, currently in interest because of the large-scale industrial development in this geographic area. The birth rate was estimated roughly to 34 births/1000 inhabitants, almost steady in the mentioned period. However, the population growth was given by the infancy death rate reduction, from 85% in the case of age 5 (at the beginning of the period) to 35% in London city (at the end of the period). The reduction of the infancy date rate was influenced by the better access of the population to healthcare facilities, vaccination and improving hygiene conditions in town, including sewers. The natural growth rate in towns (without immigration) came positive after the beginning of the nineteenth century when the number of births (evaluated by baptism records) overcome the number of deaths. The general population almost triple it in the mentioned period. The estimated world population rose from an average estimated 750 billion people (in 1750) to 1,200 billion people (in 1850). The time span was altered to fit the existing estimation.

The First Industrial Revolution attracted the population from villages to towns, assuring the basic goods and healthcare services, possible by concentrating the population in towns. According to the source [53], the GDP per capita rose from 2,092.98 £ (for 1784) to 3,683.75 (for 1869). The values were adjusted with the inflation rate and prices for 2013. The new social class, the workers, replaced the old form of slavery in most countries. The wage is the payment for the disposed work. The work schedule and work conditions are overstressed, limiting the life expectancy of the workers. As a general conclusion, the First Industrial Revolution, in terms of management structure, established the company as the form of organization, introduced a new social class as workers, and introduces the wage as the form of payment. The need that has been accomplished by the First Industrial Revolution using the Maslow hierarchy can be appreciated as physiological, with access to basic goods and services, necessary for living.

The Second Industrial Revolution came with more disruptive technologies and management structures, including the assembly line, labour division and business functions. Mass production lowered the price of most commodities and gave access to the workers. The sanitation and healthcare services were largely improved, including the life quality in cities. The large-scale sales of automobiles and trains as mobility support revolutionized the living, by adding mobility to workers, and the positioning of factories. For the sake of comparison, the same sources of data are used. The average world life expectancy, started from 41.22 years in 1869, calculated for eight European countries, for the existing recorded data, to 55.63 years in 1969 (with uneven distribution around the continents, Asia 53.93, Americas 64.63, Europe 70.15 and Africa 45.15). The United Kingdom started in 1870 with a life expectancy of 40.65 years and ended in 1969 with an astonishing 71.84 years. In the same manner, for the US, the first record appreciated the life expectancy in 1880 from 39.41 to 70.58 years in 1969. In terms of population growth during the Second Industrial Revolution, the average estimated number of people was 1,650 billion in 1900 and more precise 3,625.68 billion, doubling the population in almost 70 years. Regarding the GDP per capita, the evolution indicated a rise from 3,927 £ for the UK in 1870 to 12,224.58 £ [53] actualized with the inflation rate and price for 2013. The same ratio (over 400%) is registered also for the US [53, 67] in 1870; the GDP per capita was estimated to be 4,803 USD and 24,165 USD in 1969 (data adjusted for 2013). The agricultural production was for the first time overrun by industrial production in the US in 1900, according to [28]. The mass production of goods and services rose the issue of mineral resources shortage, such as iron, oil, coal etc. The shortage of resources caused two World Wars, with a great impact on the population and GDP growth. Also, the mass production generated several economic crises when the offer overwhelmed the request. A new social class appeared, the middle class, with sufficient purchasing power to access the most category of goods.

Starting from the first scientific production management architecture, introduced by Frederick Winslow Taylor by "The principles of the scientific management" and simultaneously were applied into the automotive factory by Henry Ford, to the smart manufacturing gathers over a century of the struggle of the companies to best fit to market demand. The second step to formalize the enterprise was done by Henri Fayol in [27].

The business function division proposed by Fayol covered the technical function, with reference to the technical capacity to produce a product, the commercial function, not only stressing the importance of supplying but also disposing of the products made, the financial function, with the role of secure the capital flow necessary for the operationalization of the other functions, the security function, covering ensuring the integrity of the assets held and ensuring the smooth management of the activity, under conflicting conditions, with the role of prevention, the accounting function as a tool for assessing the operationalization conditions and providing accurate and immediate information that can be used to assist the decision, and administrative function, taking into account decision-making, at an operational level and the implementation of management principles.

The hierarchical approach of the manufacturing systems continued in the Second Industrial Revolution, with new influences for the time and movement study (Frank and Lillian Gilbreth), to increase the productivity and limit the fatigue of workers, quality assessment and cost control (Edward Deming, Joseph Juran). The cooperation of the workers in a company was early studied by Cherster Barnard and Mary Parker Follet and deeply explained by Max Weber.

The second way of expressing the functions of the enterprise, in this case in the number of four, is presented by Boris Evgrafoff in 1970, in the paper [20], which reorganizes the internal business processes in the form of [1, 15, 49, 50]:

- Management function, by collecting information assisting decision-making, decision-making, information and awareness of the members of the organization regarding the decision taken
- Distribution function, with reference to the conduct of market research, sales, sales management and after-sales services
- Production function, aiming at production preparation, production management, quality control etc.

- Logistical function, which ensures financial, human and material resources for the production process, including research and development.

The Second Industrial Revolution, as conclusion might be seen as corresponding to accomplish the safety level of the Maslow hierarchy of needs, where large access to commodities, goods and services rose the life expectancy, is also positively influenced by large access to healthcare services and large use of antibiotics. The Second Industrial Revolution add the middle class as a new social class, being the backbone of a developed society. The industrial production exceeded agricultural production for the first time in history, and the offer overwhelmed the request, generating an economic crisis. However, in this period the manufacturing process is largely dependent on the human factor, the working condition and crises, leading to unions organization and strikes as a form of reposting [49, 50].

The Third Industrial Revolution is assessed by using large-scale automation and later by computers in the manufacturing process. The enhancing of the coordination of the manufacturing facilities make possible the birth of a new paradigm of manufacturing, largely based on collaboration and independence.

In the paper [51], M. Porter proposes the concept of the value chain, organizing internal processes according to the flow of transformation of a system's inputs into outputs, thus proposing the following functions, which will be used, by addition, in the current statistical system:

- Core functions directly refer to the physical creation, sale, maintenance and support of a product or service. They consist of the following:
  - Inbound logistics, representing the processes of reception, handling and storage, with a view to being transformed into operationalization into finished products
  - Operations, including processes for the transformation of raw materials and materials into finished products that are sold to customers: production planning, processing, assembly, technical quality control etc.
  - Outbound logistics, all processes of collection, handling, storage and distribution of the product or service produced to the customer
  - Marketing and sales, customer awareness processes of the value, products or services offered, bidding, sales and sales management
  - Service, the totality of product value maintenance processes throughout the lifecycle
- Support functions, which support the main functions, in the process of transforming system inputs into outputs:
  - Procurement, the process of obtaining the necessary resources for operation, the selection of suppliers and the purchase of raw materials, equipment, materials necessary for the transformation of system inputs into outputs
  - Technological development, development processes and knowledge base protection, including research and development and improvement of existing products and processes

– Human resources management includes recruitment, hiring, training and employee motivation processes
– Organization infrastructure by providing support systems for day-to-day operations: management, accounting, finance, strategic planning.

The paper [45] presents a comparative study of the models of the company's functions, used for statistical purposes, from 2007 to 2012, by the 2007 International Survey (Eurostat), 2012 International Sourcing/Global Value Chains Survey (Eurostat), 2010 National Organization Survey (USA: [4]), 2009/2012 Survey of Innovation and Business Strategy (Statistics Canada), which distinguishes the following observations, on their identification and grouping [16, 24]:

- Only one main function (core business function) is retained, which the authors, as well as 2009/2012 Survey of Innovation and Business Strategy (Statistics Canada), propose to be divided into the production of goods and the production of services
- Support functions vary between the models presented, keeping a common trunk represented by the distribution and logistics function, the Information Technology and Communication) service function, the management and administration function
- Differences are given by highlighting marketing, sales and post-sales services, including helpdesk and call centre services, which is divided into the 2010 National Organization Survey (USA: Brown and Sturgeon), 2009/2012 Survey of Innovation and Business Strategy (Statistics Canada), and the research development function, in the 2012 International Sourcing/Global Value Chains Survey (Eurostat) and the 2010 National Organization Survey (USA: Brown and Sturgeon) are combined with engineering and related technical services.

The model used by EUROSTAT [19] for reporting maintains the R&D function, as a distinct support function from engineering and technical services, in a model with a single main function and six support functions (distribution and logistics, marketing, sales and after-sales services, information and communication technology services, administration and management, engineering and associated technical services and research and development).

The collaboration, as a mark of "Belonging" need of the Maslow hierarchy of needs, came into the manufacturing paradigms, with a series of approaches cumulatively presented in Table 2.

The challenges regarding the new possibility of coordinating multiple manufacturing facilities, using the widespread of computer networks and computer software in all aspects of operational management and production management, correlated with the globalization of enterprises, were addressed using biological models (bionic manufacturing systems) or abstract, using mathematical models (fractal company). The main concept was to enhance the business units with a similar function that may play on the local market. Also, the business concept of a single enterprise was replaced with temporary alliances (virtual enterprise). The switch from mass production to a customer-centred approach, because of overproduction, was generating the development of new needs and sophistication of the existing ones.

Table 2 Collaboration architectures of the manufacturing systems

Manufacturing architecture	References
Bionic manufacturing systems	Tharumarajah et al. [62], Ueda [64]
Flexible manufacturing systems	Berman and Maimon [3], Kassicieh and Schultz [33], Slomp and Zijm [59]
Autonomous and distributed manufacturing systems	Duffie and Prabhu [18], Kádár et al. [35], Ryu and Jung [55], Srai et al. [59]
Agile manufacturing	Shewchuk [57]
Multi-agent autonomous systems	Franklin and Graesser [22]
Holonic enterprise	Mella [41], Tharumarajah et al. [62], Tharumarajah et al. [63], Ulieru et al. [65]
Fractal company	Deng et al. [14], Warnecke [70], Warnecke and Warnecke [71]
Convergent enterprise	Nau et al. [44], Shah and Rogers [56]
Virtual enterprise	Camarinha-Matos and Af- sarmanesh [8], Carutasu and Aurite [9], Guran et al. [17], Dragoi [26]
Next-generation manufacturing systems	Bunce et al. [6], Kurihara et al. [34], Okabe et al. [46]

In conclusion, the Third Industrial Revolution brought as a novelty to the customer-centric approach, the sliding from the hierarchical manner of an organization to multi-polar and coordination organization, imposes the automation of processes, using IT deeper in the operational management and processes management. The average world life expectancy rose by almost 10 years in only 40 years' time. The GDP per capita continues to rise and the work condition largely improved, the human resource becoming the most valuable resource of a company. However, the difference between countries regarding technological advancement and access to innovation has been deepened. Thus, it explains the polarization of wealth among the world, with a high differentiation from primary resources (food, water, shelter) to more elevated ones (arts, education, medical care). The Third Industrial Revolution correspond to "Belonging" level of Maslow hierarchy, with a great accent to "collaboration" between business units, replacing the hierarchical way of thinking.

The claimed Fourth Industrial Revolution, purely announced by the German consortium as a desiderate, without having proper implementation or proofs [32] gathered various emergent technologies and foreseen an integration in the manufacturing process.

The model of the new was enthusiastically adopted by a large community, being a great marketing driver for the software industry. Nevertheless, the concept itself has a great value, by introducing the machine-to-machine collaboration, as a strong possibility, without human intervention, human-to-machine collaboration, as pairs or avatars, and the old human-to-human collaboration, but renewed with new augmented tools. The real impact, after using the sensing ability to decision-making artificial

Table 3 Referential for new Fourth Industrial Revolution terms

Terms/concepts	References
Industry 4.0	Cotet et al. [12], Gorecky et al. [25], Marr [38], Melanson [40], Shrouf et al. [58]
Industry 5.0	Cotta et al. [13], Özdemir and Hekim [47], Paschek et al. [50], Sołtysik-Piorunkiewicz and Zdonek [60], Vogt [69], Zengin et al. [73]
Smart manufacturing	MacDougall [37], Qi and Tao [52], Vater et al. [68]

entity, is the passing the decision-making process from human to robots (in the form of physical or software form of artificial intelligence). The next step was to prevent the human totally replacement by robots in the enterprise architecture, by the Industry 5.0 concept (released by EU Commission [13]), with a human-centric view, with a sustainable and resilient approach to manufacturing. The term smart manufacturing was a generic term where "smart" symbolizes the use of sensors and artificial intelligence, which was also debated in the period. A selective referential for the presented terms is enhanced in Table 3.

The main barriers to the adoption of Industry 4.0 are presented in the paper [36]:

- Interaction between operators and equipment by limiting the ability to make decisions according to the state of operation of the equipment in real time
- Machine centres, by grouping identical machines, forecasting methods that do not consider the particularities of operation and the operating environment
- Quality of products and processes, by the absence of a control reaction in the manufacturing process
- State and speed of operation of cloud technologies and the analysis of large volumes of data, and these technologies being at the beginning of the lifecycle.
- Network of sensors and controllers, by their degradation or malfunction, which may lead to inappropriate decisions.

It is noted that starting from the requirements of the evolution of integrated information systems for the transition to cloud architectures, presented above, the concept of Industry 4.0 is in fact a customization of it, by using these in the industrial environment.

The new concept of Industry 4.0 has no significant impact yet and it is too early to be considered as an Industrial Revolution. However, significant steps forward were made in the conceptualization of the human-centric approach, the human-to-machine and machine-to-machine collaboration. The Fifth Industrial Revolution, with no human intervention, is more like an ending point right now, with an expected concentration of human attention to more altruistic and creative goals, having no pressure of fulfilling basic or more elevated needs.

2 Virtualization on the Architecture of Information Systems at Organizational Level

In cloud infrastructure, computing power is provided by data centres, which include servers and data storage systems. It can accommodate most types of integrated information systems [11]. The customers pay flexibly, depending on the resources used, based on a monthly fee. Cloud service users also reduce TCO by eliminating usage license spending, hardware architectures needed to store data, unnecessary space to place such equipment and increased data security [10].

From a business model point of view, the components of the cloud services are:

- Customers, who access the service via mobile devices or computers, with the benefits of reducing the costs of purchasing and maintaining hardware infrastructure, reducing security costs, low energy consumption etc.
- Data centres, which consist of server collections. They can be arranged in the same space, in the same building or in a space outside the organization and may contain virtualized servers with installed applications
- Distributed servers, which are in the same organization, but in different geographical locations, to ensure disaster redundancy (power outage, etc.).

Data centres can have several functions, such as transaction processing centres, multimedia content delivery centres; data centres to perform complex simulations and data processing operations for integrated information systems.

General models of virtualization contain the following types of cloud services [31]:

- IaaS (Infrastructure as a Service) is a cloud service model in which a provider leases a technology infrastructure, i.e., virtual servers, that can replace existing systems completely or partially within the company. IaaS allocates the entire suite of infrastructure resources and facilities (electricity, cooling solutions, etc.) for hosted hardware platforms
- PaaS (Platform as a Service) is a type of cloud service in which a provider offers software development and hosting solutions. It is used by companies to develop and market host solutions on demand or provide services to other companies. PaaS is created using an IaaS infrastructure that adds to an additional level of integration with different application development environments
- SaaS (Software as a Service) is a model in which a provider provides web services for applications that it makes available to end-users. Such services are generally intended to replace applications installed by users on their local systems. SaaS (Software as a Service) is based on a PaaS infrastructure, providing an autonomous operating environment used to provide the ultimate user experience, including ERP systems, multimedia applications, accounting programmes etc. (Figs. 2 and 3).

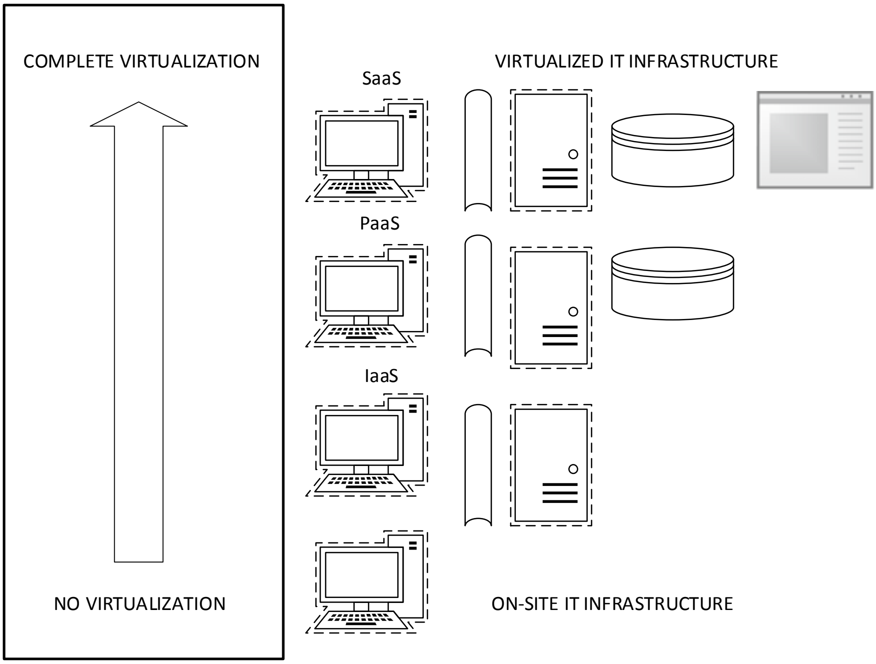

Fig. 2 IT infrastructure transition to cloud architecture

Another study concerning cloud adoption and related technologies states, in 2020, a massive option to the companies for hybrid architectures where the private cloud tools are combined with public ones, rising to 78% of total users [21].

The emergence and development of IoT (Internet of Things) devices lead to the need for organizational integration of such devices. The Garner report [23] shows that even during the pandemic period, the IT investments that dropped during 2020 is expected to rise during the next period, using cloud technologies and IoT as a method to reduce costs, with examples. The following figure shows a reference architecture for a hybrid cloud platform, using Microsoft Azure, in which one can identify the following:

- Company's infrastructure, organized in the form of a private cloud, managed by an internal data centre, which manages various applications as well as the integrated ERP, CRM or SCM computer system, which ensures increased data privacy
- Public cloud platform, providing specific collaboration tools through SharePoint and Office 365
- Azure IoT platform, necessary for integrating IoT devices into the company's workflow.

The detailed map of the IoT Azure services is presented graphically below, having as distinctive levels data connectivity, data processing analytics and management, and presentation and business connectivity (Fig. 4).

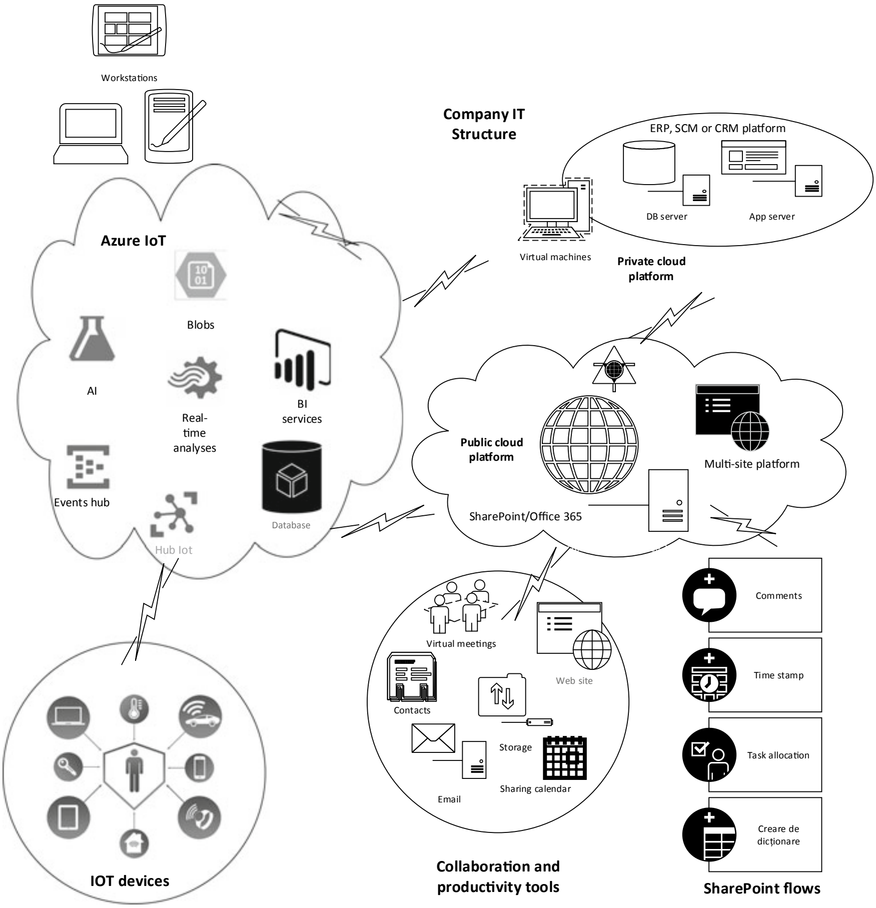

Fig. 3 Hybrid reference architecture for cloud services

3 Production Systems—Trends and Perspectives

From the point of view of current production systems, the benchmark architecture expected to be implemented in the future is Industry 4.0, with the updates of Industry 5.0. The Industry 4.0 concept enables the integration of the activity of cyber-physical systems by developing the communication and real-time cooperation capabilities of human operators and robots, based on the following technologies:

- Implementation of the sensor capacity of the IIoT (Industrial Internet of Things) production systems, aimed at monitoring, controlling and organizing production and predictive maintenance
- Analysis of the large volumes of data provided by IIoT sensors and their use in optimization and prediction algorithms

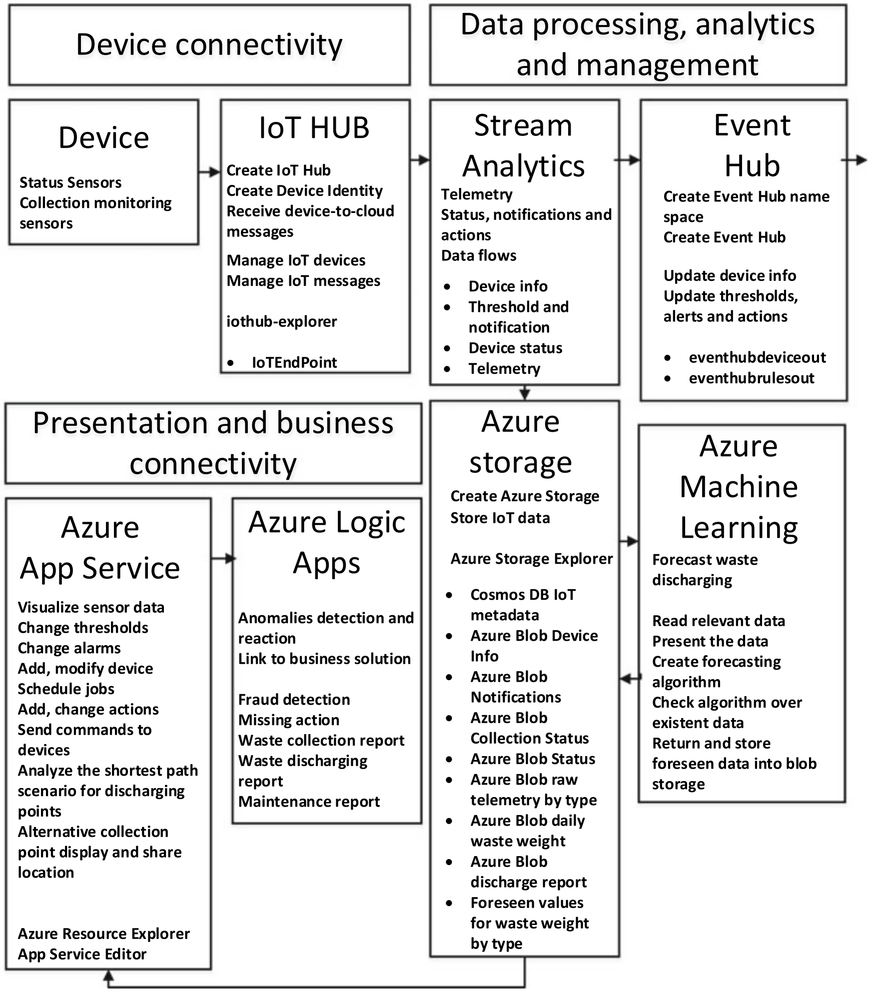

Fig. 4 Detailed map of IoT Azure services

- Systems integration used at the organization level, in the form of extensive platforms, integrating suppliers and customers, with enterprise resource management modules and product data management, throughout the lifecycle, simulation of the production process and optimization of production flow
- 3D printing, by additive manufacturing processes, aimed at reducing production time for unique products and prototypes and eliminating transport times, for certain categories of parts, in the service activity (Fig. 5)

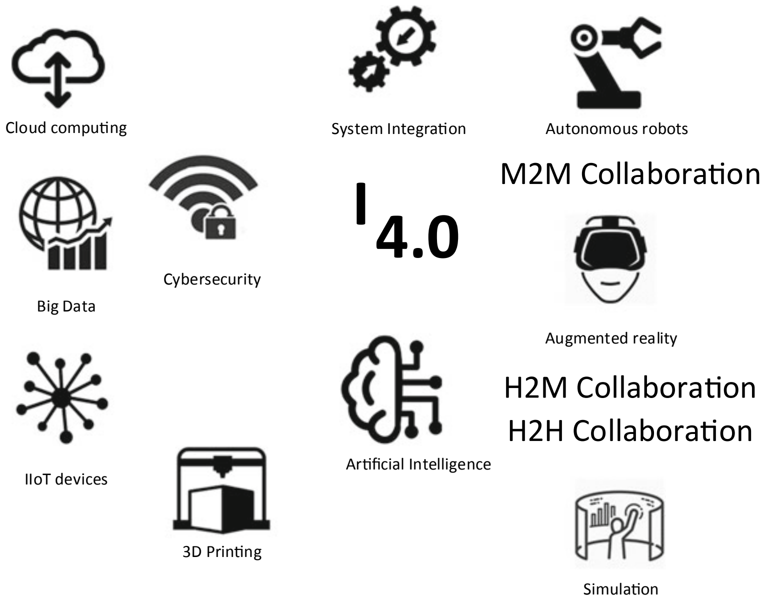

Fig. 5 Industry 4.0 technologies

- Augmented reality, by accessing contextual information for operations carried out by human operators as decision-making support in the production and service activity
- Cloud computing, as a support structure for the integration of information systems and sensor data
- Simulation and artificial intelligence, concerning the existence of a digital clone of physical systems with a degree of advanced behaviour fidelity, with which simulations of real-time production streams can be carried out, their optimization and production control
- Autonomous robots, by connecting them to the computer structure of the organization, having the capacity to communicate and work together, both with human operators and other machines, equipment, and production facilities in real time
- Cybersecurity, in view of the increasing volume of data being circulated, the implementation of mandatory security policies and the potential as a source of bottlenecks or production shutdowns following cyber-attacks.

It is noted that starting from the requirements of the evolution of integrated information systems for the transition to cloud architectures, presented above, the concept of Industry 4.0 is in fact a customization of it, by using them in the industrial environment.

The forecasts presented in [29], by IQMS, manufacturer of ERP systems, integrated into the 3DExperience platform owned by Dassault Systèmes, identify the main trends in production systems, how manufacturers intend to achieve their revenue growth targets, operational improvements, digital transformations and the launch of new products and services in 2019, and in [30]. The studies identified the following opportunities for the development of production systems (presented by comparison in Table 4).

Autodesk Company presented in 2019 five major trends for production systems on the integration or increasing share of various technologies at the organizational level:

- Adoption of Industry 4.0 production architecture as a standard for future production systems, characteristically having a large volume of data used and the possibility of the informational interconnection of the components of the production system
- Increase purchase costs for robots and drones, tasks such as 3D exploration or visual inspections to be automated
- Improving interconnectivity by adopting the 5G standard, allowing the widespread adoption of artificial intelligence and data collection and equipment control using IoT in real time
- Inclusion of blockchain technology in the information architecture of production systems, prerequisites for increasing the accuracy of available data through the existence of shared data block, data can be viewed and used in decision support at all levels of the production system
- 3D printing expansion as a manufacturing process by reducing manufacturing time and costs for various applications.

The same company presented in [2] the prediction for 2021 in the case of the manufacturing systems evolution:

- Orienting to more personalized production, the customers valuing the real individual needs, pressing to the manufacturers to provide more individualized products
- Refining the smart products' design, with more understandable data and aggregating into more comprehensive form, strongly related with the individual behaviour, sensing capability being not enough without a proper interpretation of the data obtained, using phone apps or web-based portals
- Imposed quarantine periods, and the temporary incapacity of workers in 2020, due to the COVID pandemic, impose the automation of most repetitive tasks, extended to all industries
- Shortening and flexibilization of the supply chain, from the same reasons explained above, during the COVID pandemic, with closed borders and production stopped because of workers temporary incapacity to work
- Integrating on-site data centres, in the construction industry and extensive use of prefabrication, shortening the construction time and saving space needed to store the materials,

Another assessment of production system trend is presented by Microsoft, identifying six trends in [42] the development of production systems:

Table 4 Prediction for the manufacturing systems by IQMS in 2019 and 2021

2019 predictions	2021 predictions
Increasing the share of the use of analysis and business intelligence tools, chain-wide suppliers, stores and management teams, through custom-integrated platforms, which will use data provided by existing systems and which will include predictive analysis or machine learning tools	Rethinking of the workers responsibilities, by automation of annoying tasks, the companies struggling to attract trained employees with enhanced digital skills
Obligation to use an enterprise resource planning (ERP) system to increase customer-centred competitiveness	ERP remain a "must have" for the industry, with real-time capabilities, and more advanced financial and sales reports, being considered the backbone of the IT system
Integrating supply chains, from the manufacturing industry, into smart grids with the real-time integration of tracking systems, aiming at increasing delivery accuracy, and improving the quality of raw materials	Use of the automated configure, price, quote tools (CPQ), to avoid the errors from human interaction, enhanced with 3D images of the products, able to implement more accurately the market strategies for a limited time
Use of Wi-Fi and IoT sensors, to the detriment of PLC or other previous systems, leading to the creation of a real-time data stream that provides information on product quality, performance and performance of the use of means of production, also used as decision support in solving operational problems by manufacturers	Adoption of real-time reporting for the supply chain and manufacturing, given by the instability of COVID pandemic, shortening the usual need of the reporting period to almost instant
Widespread adoption of robots, due to the chronic lack of labour in the manufacturing industry, accompanied by increased demand for large-volume parts and assemblies among mid-level producers, with a view to increasing and maintaining market share	Due to the COVID pandemic instability, the customer preferred the suppliers who can deliver faster and predictable, the manufacturers integrating the ERP with the CAD systems
Imposing as a standard of manufacture intelligent machinery and equipment at all levels of production	The IoT ability inclusion in the machine tools, enhancing the existing predictive maintenance function with dimensional control, integrated with the quality control module
Widespread adoption of IIoT (Industrial Internet of Things) devices, particularly not only in real-time monitoring of operations but also in predictive maintenance or quality assurance	Expanding the traceability for the products, especially for food and beverages, increasing the production conformity with various faster changing regulation, companies being interested in obtaining certifications or to make external audit to prove the quality and traceability of the products
Implementation of blockchain data structures at the production activity level, through relationships with similar structures at supplier level, operational planning, and the emergence of new business models	Increasing the sustainability for the manufacturing, in terms of reducing the generated waste, or to acquire more efficient facilities for energy production
Migrating production to smart products with Product as a Service business models by ensuring a steady flow of sales and revenue, respectively, by increasing the duration of use and the possibility of updating the performance of the product	More extensive the use of digital twins and simulation in the smart factory, at workplace level, to improve the safety and the efficiency of the workers

(continued)

Table 4 (continued)

2019 predictions	2021 predictions
Increase cybersecurity spending and improve the organization's internal data protection	

- Integrating the IT system into operational technology by adding communication and data collection capabilities to old equipment, using cloud-computing infrastructures, integrating existing command and control software systems, implementing IoT at all levels of the production system, increasing human–robot interaction and adopting efficient and environmentally friendly technologies
- Adoption of the Product as a Service model, by sharing products or shortening the supply chain of the product, due to the decrease in purchasing power and the tendency to federalize and depersonalize the means of production. A trend with potential is Manufacturing as a Service, in which the production order is transmitted through control platforms, the actual production facility being unknown to the beneficiary, the decision of location belonging to the proprietary group of production facilities. Similarly, emerging services are supported by industry profile, such as Design as a Service, Experimentation as a Service, Equipment as a Service, Simulation as a Service, Management as a Service, Maintenance as a Service and Integration as a Service
- Widespread implementation of the smart production concept, through the integration of artificial intelligence and machine learning at the operational level, leading to lower production costs, shortening production times, avoiding bottlenecks and failures through productive maintenance, adopting blockchain technology at the organizational level and including supply in the smart value chain
- Replication of physical production systems in the virtual environment and use of these models for design, operation, simulation and diagnosis, with the aim of reducing manufacturing defects at the project level. Also, it is foreseen to extend additive and subtractive production processes in the production of goods, as well as the use of new materials in these processes. Another trend is the use of autonomous equipment and machinery capable of operating without human intervention or by limited intervention in automated workflows. The expansion of human–machine interaction capacity, as well as the capitalization of the operating ability, is estimated to be achieved by using augmented and virtual reality as a component part of operations
- Adapting business processes to the available human resource by increasing the share of the active population after 55 years, correlated with the competition of digital natives, leading to changes in the way of inter-personal interaction, by adapting IT tools as a way of conversation and information, at the expense of direct conversation. Another direct consequence will be the change in the way of working in companies, requiring a focus on employee availability, and supporting the entrepreneurial spirit, by participating in the decision-making process. It is to

be expected, by changing the age structure and adopting information technology, to have a gap, through the prism of people's abilities,

- Increasing the uncertainty of the business environment by introducing new rules (GDPR) or excessive politicization by delineating new markets through new trade agreements and lack of predictability on industrial development. In this respect, the additional costs of ensuring the protection of personal data at the company level, requirements for concrete data protection measures at the company level and the obligation to report security incidents are underway. In terms of the delimitation of new markets and trade agreements, the most eloquent examples of 2019 are the trade agreements and customs policy of the United States of America, in particular with China, but also the imminent exit of the United Kingdom from the European Union.

The 2020 point of view of Microsoft, regarding the future of the manufacturing systems is presented in [43], concerning the next tendencies:

- Data unification and availability extension is the most important trend for the manufacturing systems, the same data being acquired, shared and used among the company, by different worker categories from various devices
- Shifting from new emergent technology adoption to an increased experience of the customer, regarding the goods and services, the customer being more careful to spend, expecting to cheaper, better and faster-delivered products, forcing the manufacturers to develop more innovative processes to reduce cost, to include more additional services and to find a faster-delivering solution, using the unified data collected in the process
- Spreading the smart manufacturing as standard, with IoT and operation technology connected, enhanced with AI capacities
- Enhancement of sustainable manufacturing and increase the safety of workers at the workplace, because of the regulatory bodies, communities and NGO's pressure
- Adapting to a more polarized workforce, with an aged population and the rise of Z-generation, necessitating more efforts of training and changing the workstyle, the workforce should adapt to very fast-changing technologies, including the organizational way of conducting business
- Increase the R&D spending, with a strong accent on rapid prototyping, digital twin, augmented reality, nanotechnologies, and simulation, to fasten the time-to-market
- Rethinking of the supply chain, as an important differentiation from the competition, adopting on large scale the traceability and prediction of delivery time, including autonomous vehicles or drones, for delivery and autonomous robots to sort and store the products inside the warehouse
- Continuous adaptation of businesses to increased uncertainty, the COVID pandemic impacted the global economy, by exposing the supply chain weakness, changing the consumer behaviour to a smarter purchase and the suppliers' temporary indisposition as a result of the imposed quarantine.

4 Conclusions

The current trends of the manufacturing systems are the result of a long evolution of technology and management style. The comparison of the industrial revolution with Maslow' hierarchy of needs, offer a clearer image of the challenges and limitations of each time span. The life quality indicators, such as average world life expectancy, GDP per capita and general population revealed a continuous improvement of the general life because of the industrial revolutions. The first section of the chapter enforced the time placement and the opportunity of the manufacturing systems evolution. Using extensively IT and other related technologies, in the manufacturing process, and in all aspects of everyday life, impacted massively the quality of life. However, Industry 4.0 become possible after the manufacturing collaborative paradigms presented (e.g., bionic, fractal, multi-agent etc.) which established the principle of operation. The impact of Industry 4.0 at the society level is too early, in historical terms to be evaluated. Furthermore, the initial concept was updated with sustainability and resilience dimensions, protecting the resources and the human-centred paradigm. Even if autonomous robots became a necessity in today industry, the role of the human workers remain decisive in the manufacturing systems, exposed also by the pandemic crisis. Globalization also showed limitations, with delivery outages or unpredictability, and more and more countries orienting to relocate the critical industries to their homeland.

The COVID pandemic impacted the manufacturing systems, by shifting the focus from the product to the customer needs. The consumer, because of cutting incomes, became more aware of the product value, carefully spending on smarter products, more oriented to their needs. The pandemic situation exposed the globalization weakness, in terms of concentration various industries in a limited geographical area, depending on international transportation to deliver goods on the local market. The supply chain flexibility and prediction were the most valuable asset in the past year. However, the already implemented IoT and AI in the manufacturing information systems must be more integrated and available to all working positions with real-time data, and more important, interpreted data using AI or other decision support systems techniques. The faster than ever-changing technologies used in the manufacturing process and in the operational chain, cumulated with the ageing of the workforce, conducted a more careful management of the human resources, the worker being exposed to a large volume of data, to support the working process. The ageing of the workforce and changing of the generation to "native digitals" polarize the teams and impose continuous training programmes. The pandemic also changes the work-style to remote work, changing the office with the employees' home, for a period of time, or alternating the office style with home. Thus, reveals an immediate necessity to offer the same data and tools by internet-based solutions. The pandemic practice might become a standard in the future, with a great impact on the workforce mobility, shortening the operation costs with offices operation cost and increasing the workers general quality of life, by eliminating the travel time to the office.

Concluding the above issues and relevant for further development, we mention the main forecast directions for the development of manufacturing systems:

- Organization of an integrated management system at the organization level, including mandatory and optional management subsystems in various fields (quality assurance, environmental protection, social responsibility, GDPR etc.) and the implementation of common procedures and measurable outcome indicators, which can be then implemented in the organization's IT system by providing decision support
- Large-scale implementation, including large companies and medium-sized and small enterprises, of an integrated enterprise resource management system capable of exchanging data with similar systems and client platforms, as well as updating real-time data on production activity
- Increasing sensory possibilities (IoT) at the manufacturing workshop level and using the data obtained in the planning, simulation and organization of ad hoc production, at the expense of centralised modelling, simulation and planning systems
- Adoption of new manufacturing strategies and processes to ensure a decrease in production time, meeting customer requirements as well as delivery forecasting, through advanced production technologies and the widespread use of artificial intelligence to reduce bottlenecks in production
- Increasing the gap in available workforce skills by segmenting it by age and digital skills. The progressive replacement of the human factor in the production process and the structural change in the way of working are also expected.

References

1. Albulescu CT, Draghici A, Fistis GM, Trusculescu A (2016) Does ISO 9001 quality certification influence labor productivity in EU-27? Procedia Soc Behav Sci 221:278–286
2. Autodesk (2021) What will manufacturing look like in 2021? The 5 top trends to watch. https://redshift.autodesk.com/manufacturing-trends-2021/
3. Berman O, Maimon O (1986) Cooperation among flexible manufacturing systems. IEEE J Robot Autom 2(1):24–30. https://doi.org/10.1109/JRA.1986.1087033
4. Brown SP (2008) Business processes and business functions: a new way of looking at employment. Monthly Labor Rev
5. Buer MC (1926) Health, Wealth and population in the early days of the industrial revolution (Routledge & Kegan Paul Ltd, Ed.; 1st ed.). https://www.routledge.com/Health-Wealth-and-Population-in-the-Early-Days-of-the-Industrial-Revolution/Buer/p/book/9781138879836
6. Bunce P, Limoges R, Okabe T (1997) NGMS—Next generation manufacturing systems (IMS Project). In: Enterprise engineering and integration. Springer, Berlin, Heidelberg, pp 274–283. https://doi.org/10.1007/978-3-642-60889-6_30
7. Camarinha-Matos LM, Afsarmanesh H (1999) The virtual enterprise concept. https://doi.org/10.1007/978-0-387-35577-1_37
8. Camarinha-Matos LM, Afsarmanesh H (2001) Virtual Enterprise modeling and support infrastructures: applying multi-agent system approaches. Springer, Berlin, Heidelberg, pp 335–364. https://doi.org/10.1007/3-540-47745-4_16

9. Carutasu G, Aurite T (2005) Partners evaluation in virtual enterprise. Univ Politeh Buchar Sci Bull Ser D: Mech Eng 67(4):25–36
10. Carutasu NL, Carutasu G (2016) Collaborative virtual environments using ERP and cloud tools. In: 10th annual international technology, education and development conference valencia, Spain, pp 5934–5944
11. Carutasu G, Botezatu MA, Botezatu C, Pirnau M (2016) Cloud Computing and Windows Azure. In: 2016 8th international conference on electronics, computers and artificial intelligence (ECAI), pp 1–6. https://doi.org/10.1109/ECAI.2016.7861168
12. Cotet GB, Carutasu NL, Chiscop F (2020) Industry 4.0 diagnosis from an iMillennial educational perspective. Educ Sci 10(1):21. https://doi.org/10.3390/educsci10010021
13. Cotta J, Breque M, de Nul L, Petridis A (2021) Industry 5.0 towards a sustainable, human-centric and resilient European industry. https://op.europa.eu/en/publication-detail/-/publication/468a892a-5097-11eb-b59f-01aa75ed71a1/
14. Deng X, Peng J, Huang H (2009) Research on the fractal company modeling based on competence. In: IE and EM 2009—Proceedings 2009 IEEE 16th international conference on industrial engineering and engineering management, pp 2136–2140. https://doi.org/10.1109/ICIEEM.2009.5344226
15. Draghici A, Mocan M, Draghici G (2011) On-line training and certification solution for business process managers. In: International conference on enterprise information systems, pp 380–389. Springer, Berlin, Heidelberg
16. Draghici A, Baban CF, Ivascu LV, Sarca I (2015) Key success factors for university-industry collaboration in open innovation. In: 8th annual international conference of education, research and innovation, Spain
17. Dragoi G, Draghici A, Rosu SM, Radovici A, Cotet CE (2010) Professional risk assessment using virtual enterprise network support for knowledge bases development. In: International conference on enterprise information systems, pp 168–177. Springer, Berlin, Heidelberg
18. Duffie NA, Prabhu VV (1996) Heterarchical control of highly distributed manufacturing systems. Int J Comput Integr Manuf 9(4):270–281. https://doi.org/10.1080/095119296131562
19. EUROSTAT (2019) Glossary: business functions—Statistics explained
20. Evgrafoff B (1973) Le gouvernement de l'entreprise. A. Colin
21. Flexera (2021) State of the cloud report
22. Franklin S, Graesser A Is it an agent, or just a program?: A taxonomy for autonomous agents. https://doi.org/10.1007/bfb0013570
23. Gartner (2021) Internet of things (IoT)—Key business insights. https://www.gartner.com/en/information-technology/insights/internet-of-things
24. Gogan LM, Rennung F, Fistis G, Draghici A (2014) A proposed tool for managing intellectual capital in small and medium size enterprises. Procedia Technol 16:728–736
25. Gorecky D, Schmitt M, Loskyll M, Zuhlke D (2014) Human-machine-interaction in the industry 4.0 era. In: 2014 12th IEEE international conference on industrial informatics (INDIN), pp 289–294. https://doi.org/10.1109/INDIN.2014.6945523
26. Guran M, Dobrescu T, Patrascu G, Carutasu G (2005) Adapting mechanical engineering curricula to virtual enterprise environment. In: 8th international conference on management on innovative technologies MIT 2005, pp 241–245
27. Henry F (1917) Administration industrielle et générale; prévoyance, organisation, commandement, coordination, controle. H. Dunod et E. Pinat
28. Hostetler LM (1936) 75 Years of American finance : a graphic presentation, 1861–1935. https://fraser.stlouisfed.org/title/75-yrs-american-finance-162/chart-5373?start_page=15
29. IQMS (2019) Top 10 manufacturing trends for 2019—IQMS. https://erpblog.iqms.com/top-manufacturing-trends-2019/
30. IQMS (2021) 2021 manufacturing trends: connecting workers will be key. https://erpblog.iqms.com/2021-manufacturing-trends/
31. International Telecommunication Union-Telecommunication Sector, S. of I (2013) Y.2060 : overview of the internet of things. https://www.itu.int/rec/T-REC-Y.2060-201206-I

32. Kagermann H, Lukas W-D, Wahlster W-D (2011) Industrie 4.0: Mit dem Internet der Dinge auf dem Weg zur 4. industriellen Revolution—vdi-nachrichten.com. https://web.archive.org/web/20130304101009. http://www.vdi-nachrichten.com/artikel/Industrie-4-0-Mit-dem-Internet-der-Dinge-auf-dem-Weg-zur-4-industriellen-Revolution/52570/1
33. Kassicieh SK, Schultz CR (1987) Decision support flexible manufacturing systems. Omega 15(6):495–502. https://doi.org/10.1016/0305-0483(87)90007-7
34. Kurihara T, Jordan J, Bunce P (1997) Next generation manufacturing systems in the IMS program. In: Information infrastructure systems for manufacturing. Springer US, pp 418–430. https://doi.org/10.1007/978-0-387-35063-9_36
35. Kádár B, Monostori L, Szelke E (1998) An object-oriented framework for developing distributed manufacturing architectures. J Intell Manuf 9(2):173–179. https://doi.org/10.1023/A:1008876114686
36. Lee J, Kao H-A, Yang S (2014) Service innovation and smart analytics for industry 4.0 and big data environment. Procedia CIRP 16:3–8. https://doi.org/10.1016/j.procir.2014.02.001
37. MacDougall W (2014) Industrie 4.0: smart manufacturing for the future. https://www.gtai.de/GTAI/Content/EN/Invest/_SharedDocs/Downloads/GTAI/Brochures/Industries/industrie4.0-smart-manufacturing-for-the-future-en.pdf
38. Marr B (2016) What everyone must know about industry 4.0. Forbes. https://www.forbes.com/sites/bernardmarr/2016/06/20/what-everyone-must-know-about-industry-4-0/#4eccfdfd795f
39. Maslow AH (1943) A theory of human motivation. Psychol Rev 50(4):370–396. https://doi.org/10.1037/h0054346
40. Melanson A (2015) Robotics and industry 4.0—Aethon Blog. http://www.aethon.com/industry-4-0-means-manufacturers/
41. Mella P (2009) The Holonic perspective in management and manufacturing. Int Manag Rev 5(2):19
42. Microsoft (2019) 2019 manufacturing trends report
43. Microsoft Dynamics (2020) Top eight trends every COO should know about the future of manufacturing
44. Nau DS, Zhang G, Gupta SK, Karinthi RR (1993) Evaluating product machinability for concurrent engineering. In: Concurrent engineering. Springer US, pp 264–279. https://doi.org/10.1007/978-1-4615-3062-6_14
45. Nielsen PB, Sturgeon TJ (2014) Using business functions to measure international trade and economic globalization. In: International conference on trade and economic globalization
46. Okabe T, Bunce P, Limoges R (1998) Next generation manufacturing systems (NGMS) in the IMS program. In: Advances in production management systems. Springer US, pp 43–54. https://doi.org/10.1007/978-0-387-35304-3_5
47. Özdemir V, Hekim N (2018) Birth of industry 5.0: making sense of big data with artificial intelligence, "The Internet of Things" and next-generation technology policy. OMICS: J Integr Biol 22(1):65–76. https://doi.org/10.1089/omi.2017.0194
48. Parente SL, Prescott EC (2003) Successes and failures in real convergence. National Bank of Poland
49. Paschek D, Luminosu CT, Draghici A (2017) Automated business process management–in times of digital transformation using machine learning or artificial intelligence. In: MATEC web of conferences, vol 121. EDP Sciences, p 04007
50. Paschek D, Mocan A, Draghici A (2019) Industry 5.0—The expected impact of next industrial revolution. In: hriving on future education, industry, business and society; proceedings of the makelearn and TIIM international conference 2019, pp 125–132. https://ideas.repec.org/h/tkp/mklp19/125-132.html
51. Porter ME (1985) The competitive advantage: creating and sustaining superior performance. Free Press
52. Qi Q, Tao F (2019) A smart manufacturing service system based on edge computing, fog computing, and cloud computing. IEEE Access 7:86769–86777. https://doi.org/10.1109/ACCESS.2019.2923610

53. Roser M (2013) Economic growth—Our world in data. Our Wolrd in Data. https://ourworldindata.org/economic-growth
54. Roser M, Ortiz-Ospina E, Ritchie H (2019) Life expectancy—Our world in data. https://ourworldindata.org/life-expectancy
55. Ryu K, Jung M (2003) Agent-based fractal architecture and modelling for developing distributed manufacturing systems. Int J Prod Res 41(17):4233–4255. https://doi.org/10.1080/0020754031000149275
56. Shah JJ, Rogers MT (1988) Functional requirements and conceptual design of the feature-based modelling system. Comput-Aided Eng J 5(1):9–15. https://doi.org/10.1049/cae.1988.0004
57. Shewchuk, JP (1998) Agile manufacturing: One size does not fit all, in strategic management of the manufacturing value chain. In: Proceedings of the International Conference of the Manufacturing Value-Chain August '98, Troon, Scotland, UK, pp 143–150. https://doi.org/10.1007/978-0-387-35321-0_16
58. Shrouf F, Ordieres J, Miragliotta G (2014) Smart factories in industry 4.0: a review of the concept and of energy management approached in production based on the Internet of Things paradigm. In: 2014 IEEE international conference on industrial engineering and engineering management, pp 697–701. https://doi.org/10.1109/IEEM.2014.7058728
59. Slomp J, Zijm WHM (1993) A manufacturing planning and control system for a flexible manufacturing system. Robot Comput Integr Manuf 10(1–2):109–114. https://doi.org/10.1016/0736-5845(93)90032-F
60. Sołtysik-Piorunkiewicz A, Zdonek I (2021) How society 5.0 and industry 4.0 ideas shape the open data performance expectancy. Sustainability (Switzerland) 13(2):1–24. https://doi.org/10.3390/su13020917
61. Srai JS, Kumar M, Graham G, Phillips W, Tooze J, Ford S, Beecher P, Raj B, Gregory M, Tiwari MK, Ravi B, Neely A, Shankar R, Charnley F, Tiwari A (2016) Distributed manufacturing: scope, challenges and opportunities. Int J Prod Res 54(23):6917–6935. https://doi.org/10.1080/00207543.2016.1192302
62. Tharumarajah A, Wells AJ, Nemes L (1996) Comparison of the bionic, fractal and holonic manufacturing system concepts. Int J Comput Integr Manuf 9(3):217–226. https://doi.org/10.1080/095119296131670
63. Toh KTK, Harding JA, Thompson D (1999) An holonic approach for the modelling of enterprise functionality and behaviour. Int J Comput Integr Manuf 12(6):541–558. https://doi.org/10.1080/095119299130119
64. Ueda K (1992) A concept for bionic manufacturing systems based on DNA-type information. In: Human aspects in computer integrated manufacturing. Elsevier, pp 853–863. https://doi.org/10.1016/b978-0-444-89465-6.50078-8
65. Ulieru M, Brennan RW, Walker SS (2002) The holonic enterprise: a model for Internet-enabled global manufacturing supply chain and workflow management. Integr Manuf Syst 13(8):538–550. https://doi.org/10.1108/09576060210448125
66. University of Missouri (n.d.) Introduction—Prices and wages by decade—Library guides at University of Missouri Libraries. https://libraryguides.missouri.edu/pricesandwages. Accessed 20 Apr 2021
67. University of Missouri (2021) Prices and wages by decade—Library guides at University of Missouri libraries. https://libraryguides.missouri.edu/pricesandwages
68. Vater J, Harscheidt L, Knoll A (2019) A reference architecture based on edge and cloud computing for smart manufacturing. In: Proceedings—International conference on computer communications and networks, ICCCN. https://doi.org/10.1109/ICCCN.2019.8846934
69. Vogt J (2021) Where is the human got to go? Artificial intelligence, machine learning, big data, digitalisation, and human–robot interaction in industry 4.0 and 5.0. AI & SOCIETY. https://doi.org/10.1007/s00146-020-01123-7
70. Warnecke H-J (1993) The fractal company. In: The fractal company. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-78124-7
71. Warnecke H-J, Warnecke H-J (1993) The fractal factory—An integrating approach. In: The fractal company. Springer, Berlin, Heidelberg pp 137–217. https://doi.org/10.1007/978-3-642-78124-7_4

72. Wortmann JC, Browne J, Sackett PJ (1993) The system of manufacturing: a prospective study
73. Zengin Y, Naktiyok S, Kaygın E, Kavak O, Topçuoğlu E (2021) An investigation upon industry 4.0 and society 5.0 within the context of sustainable development goals. Sustainability (Switzerland) 13(5):1–16. https://doi.org/10.3390/su13052682