Research on the Value Chain as a Strategic Management Tool for the Digital Enterprise

Istriteanu S. and Gheorghe G.

Abstract—**The scientific paper summarizes the definition and structures of main and secondary activities, the value chain, the means of carrying out the cooperation of the economic environment with research as a necessity for increasing innovation in digital enterprises in Romania and the research results and contributions on mechatronic and cyber-mixmechatronic systems, technological platforms - cobotic platforms, platform networks and networks of technology and cobotic platform networks for the digital enterprise and for the smart industry as a whole (4.0).**

These concepts and constructive robots that have emerged as results of the research efforts in INCDMTM are presented concretely, as an important part in the realization of some of the parts of the digital enterprise and of the intelligent industry.

Index Terms—**Value chain, high added value, innovation, Industry 4.0, digital manufacturing, mechatronics.**

I. Introduction

The value chain is a model developed by Michel Porter and is a very good strategic management tool, which describes how **value** is created for the company, in an industry or globally. Moreover, the intelligent application of this model can lead to the identification of opportunities required to reformulate strategies and operations within an enterprise, an industry, or globally. At the same time, in this model there are two types of activities in which enterprises / industries are engaged: core activities and support, or secondary activities. In terms of focus, the main activities transform raw materials into products and services and ensure the delivery of the benefits expected by customers. Additionally, support activities contribute to the adequate and efficient development of the main activities.

The structure of the main activities of the value chain includes:

- **Input logistics**: refers to the relationship with suppliers and includes all activities involved in the (own) transport, reception, storage and further supply of raw materials;
- **operations:** refers to the processes of transformation of raw materials into finished products **and** services;
- **output logistics:** refers to the relationship with direct customers and **includes** all activities involved in the reception of production, storage and delivery of finished products;
- **marketing and sales:** represent the activities carried out in the **relationship** with customers and consumers in order to inform them about products / services, to determine the purchase decision and to facilitate their purchase;
- **post-sale services:** their role is to ensure / maintain the proper **functioning** of the products / services after they have been delivered to clients and consumers, respectively.

The structure of the secondary activities of the value chain includes:

- **supply:** it has the role of purchasing the raw materials and resources needed by the company;
- **technological development:** it has the role of making available the necessary equipment, technologies, knowledge and organization in the processes of transforming raw materials into finished products;
- **human resources management**: includes all activities of **recruitment**, evaluation, selection, development, promotion, reward and termination of employment;
- **digital enterprise infrastructure**: includes all activities to support and bring together the various entities within the enterprise (planning, accounting, legal aid, etc.). In its logical interpretation, the value chain of a digital enterprise is **closely** linked to the business model and business strategy, and how its management conceives value for customers and shareholders determines the type, nature and volume of activities included in the value chain. And the value chain of an industry refers to the main activities that generate value across the entire chain of digital enterprises involved in the realization of a smart product or high-tech service. Also, the global value chains, developed by multinationals, involved investments abroad and the establishment of subsidiaries to support the activities left "at home". To maximize profits and increase economic efficiency, multinationals locate research, development, design, assembly, intelligent component production, marketing and branding in different countries around the world, thus extending the concept of value chain to "value system", Which applies to the entire chain of suppliers, distribution networks and buyers.
- The analysis of the chain and the value system **provides** information by added value. Industry has an important hub function for value chain creation and thus represents more than a contribution to macroeconomic value creation.
- In Romania, the value chains were broken in the process of **economic** liberalization.

II. Cooperation of the Economic Environment with Research — A Necessity for Increasing Innovation in Digital Enterprises in Romania

The matrix of the cooperation of the two fields in the

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digital enterprises, invokes:

- innovation and knowledge transfer in industry 4.0;
- adopting a much more strategic approach in all aspects;
- highly qualified human capital is the essence of digital innovation;
- innovative SMEs are witnessing change by generating new products and smart technologies;
- production of knowledge through scientific knowledge;
- transmitting knowledge through education and training;
- dissemination through information technologies;
- digital transformation in marketing;
- information security in the digitalization of the enterprise;
- integration of harmonized, consistent and up-to-date data;
- the idea of intelligent production focused on people and machines;
- the necessary training for the configuration of the factories of the future systems, for the cross-sectoral education, etc;
- mobility of workers and careers;
- digitization of industrial production;
- real-time simulation of an integral part of the entire value chain;
- promoting cyber-physical and cyber-mix-electronic systems;
- combining national concepts at international level;
- system level standardization;
- addressing the human-intelligent machine (cobot) and the intelligent machine cooperation paradigm - intelligent machine for intelligent manufacturing;
- manufacturing process - factories - automation practices;
- the combination of virtual and real features;
- the future digital factory grows worldwide;
- approaching the paradigm of concepts of the factory of the future;
- the open value chain;
- flexible cyber production;
- digital manufacturing cantered on man-digital machine;
- IT systems new relationships between people - jobs - digital factory;
- new business models;
- crowdsourcing;
- the symbiotic ecosystem;
- advanced manufacturing (USA);
- e-factory (Japan);
- Industry 4.0 (Germany);
- intelligent production (China);
- the COP 21 agreement in Paris and the UN Sustainable Development Goals (SDGs).

III. Results of Research and Contributions on Mechatronic and Cyber-Mixmechatronic Systems, Technology Platforms, Cobotic Platforms, platform Networks and Technology and Cobotic Platform Network Networks, for the Digital Enterprise

A. Results of Research and Contributions on Mechatronic and Cyber-Mixmechatronic Systems / Equipment / Robots

- INCDMTM Bucharest, within the research laboratories, approached research-development-innovation activities, creating mechatronic and cyber-mixmechatronic systems / equipment / robots, as follows:
  - Intelligent mechatronic and cyber-mixmecatronic system for ultra-precise positioning (Fig. 1).

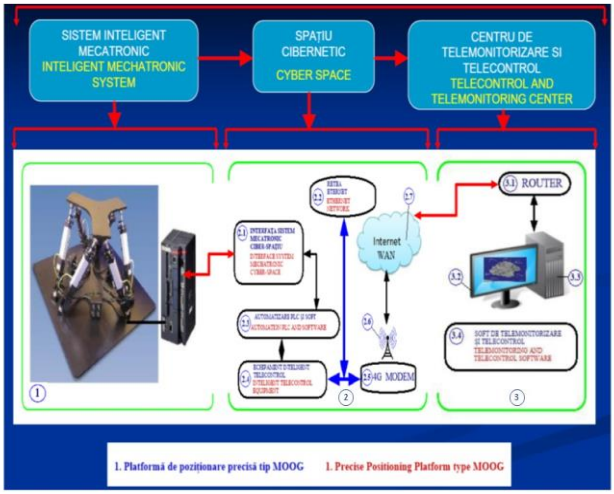

Fig. 1. Intelligent mechatronic and cyber-mixmecatronic system for ultra-precise positioning

This intelligent system is designed and built, based on the micro-nanohexapod in 6D coordinates (x, y, z, θx, θy, θz), ultra-precise positioning, made on the principle of a kinematics - parallel (Steward platform), with small base superior that moves in plane-parallel spaces, so necessary for the applications of high-precision microscopes - the atomic force microscope, etc.

This intelligent system can be integrated with the components of the cyberspace, for the transmission of information flow, through the Internet and industrial Ethernet, to the workspaces of the intelligent manufacturing processes of the beneficiary.

The remote monitoring and control centre, coordinated by the collaborative operator, has the possibility of telemonitoring and remote control of the intelligent system, directly to the beneficiary by opening the remote dialogue between the beneficiary (applicant) and the intelligent system provider.

INCDMTM Bucharest, in its research – development - innovation activity, designed and realized the 4D mechatronics and cyber-mixmechatronics system, in original constructive solutions, combining 3 linear electric axes with a rotating axis and with a multidirectional electronic probe. The whole 4D system is positioned on an anti-vibration table with an integrated air cushion (based on gas dynamics).

A separate construction contains the control, action and command panel of the intelligent system, coordinated by the operator who monitors the industrial control process.

The working space of the intelligent system is limited by a frame construction with transparent plastic side walls, and the surface in front of the work table is limited by optoelectronic sensory barriers in order to prevent hazards during the operation of the system, by means of interrupting the measurement process in case of unauthorized intrusions into the workspace by unauthorized personnel.

The monitoring of the intelligent system in the workspace is done through the dashboard of the intelligent system

operated by the collaborative operator.

The intelligent system is completed with other components to take over the information flow of the 4-axis sensors, to provide images of the measurement process, to transmit via the Internet and the industrial Ethernet of the applicant (beneficiary) the functional and technical information on the intelligent system and any other information needed to monitor the operation of the device, regarding any failure that may occur, etc.,

These information transmissions are made by the collaborative operator, directly to the beneficiary, through the remote operation and remote-control centre.

This intelligent system designed by INCDMTM by integrating original solutions is intended for integration in digital enterprises and for the digitization of measurement processes related to industrial processes. This integration in digital enterprises is part of a first stage of digital transformation of enterprises.

B. Research Results and Contributions on Mechatronics and Cyber-Mixmecahtronics Technology Platforms

- INCDMTM Bucharest has designed and developed mechatronic and cyber-mixmechronics technological platforms, as follows:
- Mechatronics and cyber-mixmechatronics technology platform for tightness testing in the automotive industry (fig. 2)

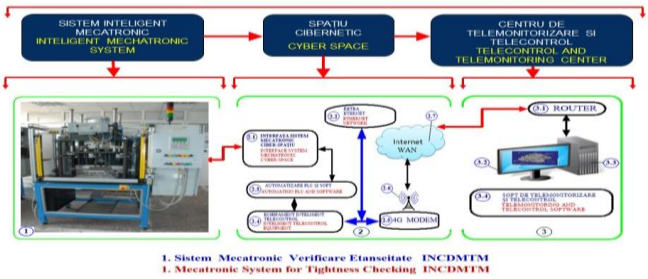

Fig. 2. Mechatronics and cyber-mixmechatronics technology platform for tightness testing。

INCDMTM Bucharest designed and built this mechatronic and cyber-mixmechatronics technological platform, in original solutions, by integrating the measuring subsystems measuring parts, the sealing fixing subsystems, the bore sealing subsystems in the cast parts, the pressurized air supply subsystems, the subsystem forms the standard pneumatic chamber, the pneumatic actuation subsystems of the sealing plungers bore car parts, the closed space formed inside the car parts and the industrial air purification installations, the digital display subsystems, the transport subsystems of indoor and outdoor parts measuring installations, measuring parts marking subsystems and marking parts transport subsystems.

The technological platform for checking the tightness of car cast parts also includes the cyberspace built through specific components (antennas, modems, etc.), through Internet and Ethernet for transmitting the flow of information, from the intelligent system and the cyberspace to the remote-control centre built based on specific components (laptop, routers, software, etc.)

The collaborative operator of the remote-control centre ensures the monitoring of the platform, its proper functioning and transmits to the local operators of the beneficiary, all the data regarding the operation, maintenance, possible spare parts replacements, etc.

These types of platforms ensure the process of initiation and construction of digital enterprise and of the enterprise of the future.

- Mechatronics and cyber-mixmechatronics technology platform for intelligent measurement and control in the field of technological equipment (fig. 3)

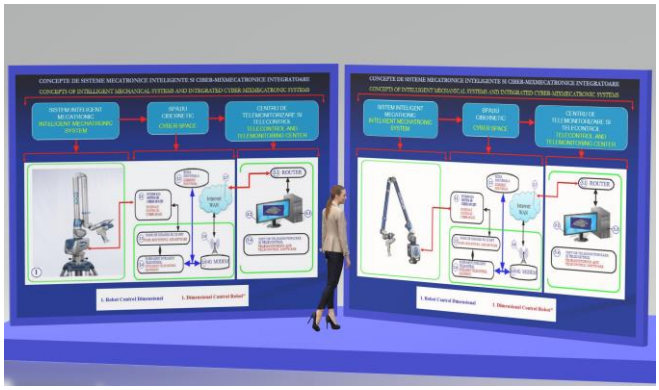

Fig. 3. Mechatronics and cyber-mixmechatronics technology platform for intelligent measurement and control

The construction of this technological platform is based on the integration in original solutions of the systems that form the platform, respectively, the constructive integration of robotic measurement subsystems, intelligent probe subsystems of measurement and control, subsystems that form cyberspace through its specific elements and subsystems. which forms the remote operation and remote-control centre.

The construction of the platform ensures the digitization of parts of the enterprise, contributing to the digitization of digital enterprises and / or the construction of the enterprises of the future.

The robotic construction of the intelligent systems in the mentioned platform is based on the construction of an articulated chain of up to 6 - 9 joints with angular position transducers, which can be manipulated through the collaborative operator.

The construction of the platform is called "an intelligent mix technology platform".

C. Results of Research and Contributions on Mechatronic and Cyber-Mixmechatronic Cobotic Platforms

The original concept of the intelligent platform was based on a complex structure formed and integrated by the robotic mechatronic and cyber-mixmecatronic system in coordinates (θx, θy θz, $\theta\alpha$ $\theta\beta$, $\theta\gamma$), the hexapodic micro-nanosystem (6D-x, y, z, θx, θy and θz), the laser probe (mounted on the hexapodic micro-nanosystem, the bracket (working table type), the 12 (twelve) coordinate digital control and action control panel, the ultra-precise positioning and measuring micro-nanohexapod controller the computer operation laptop, the anti-vibration table of the mechatronic and cyber-mixmecatronic system in coordinates, components and structures for the cyberspace (antenna modems, internet, Intranet, etc.) and the remote measurement and telecontrol centre (remote). The overall construction of the cobot intelligent platform, originally designed, actually includes

the HARDWARE and SOFTWARE of the cobot intelligent platform.

- intelligent mechatronic and cyber-mixmechatic cobotic platform with two micro-nanohexapods in tandem (Fig. 4):

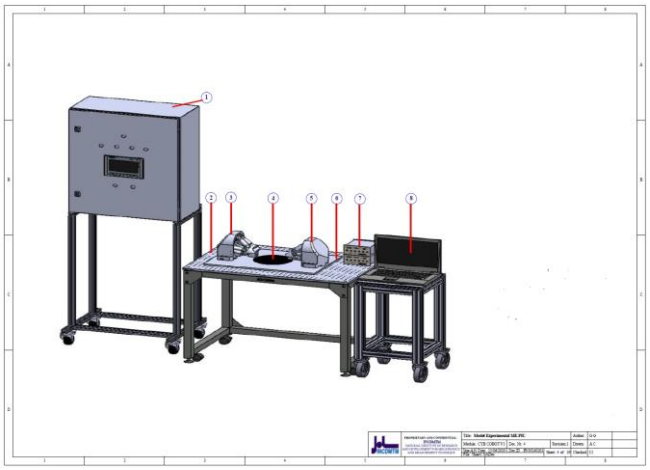

Fig. 4. Assembly of intelligent mechatronic and cyber-mixmechatic cobotic platform with two micro-nanohexapods in tandem

- The original design of the smart platform was based on a complex structure formed and integrated from the mechatronic and cyber-mixmecatronic micro-nano-hexapod in coordinates (6D - x, y, z, θx, θy, θz) in tandem with micro- the mechatronic nanohexapod in coordinates (6D - x, y, z, θx, θy, θz), the controller for the two micro-nanohexapods, the control panel, actuation and control, the anti-vibration table for the positioning of the two micro- nanohexapods, for technological and measurement activities, computer operation laptop, workpiece with optical micro-kit, support plate for positioning the two micro-nanohexapods in coordinates, components and structures for cyberspace (modem , antennas, internet, intranet, etc.) and teleoperation and remote control (remote).• The overall construction of the cobot smart platform, originally designed by the authors, actually includes the HARDWARE and SOFTWARE of the cobot smart platform.

The overall construction of the intelligent cobotic platform in original design, identifies the original solutions, as follows:• the free positioning of the micro-nanohexapod of the base of the measuring part, ensures the permanent existence in the measuring space of the measuring part, eliminating the positioning imposed on the measuring part; this positioning ensures the use of the entire workspace for the part measurement process, increasingly expanding the metrological measurement possibilities.

- The combinatorial and structural construction of the component subsystems of the intelligent platform, ensures the metrological functionality of the metrological measurement processes, i.e.;
  a) integrated construction of the anti-vibration workpiece on the air cushion (gasostatics and gas dynamics);
  b) integrated construction of the intelligent platform assembly - controller system - computer operation laptop;
  c) integrated IT construction - remote teleoperation and telemetry process:
     i. cyberspace - Eternet - Teleoperation and remote-control centre;
     ii. Eternet – Internet – Teleoperation and remote-control centre;
     iii. etc.

D. Research Results and Contributions on Mechatronic and Cyber-Mixmechatronic Platform Networks

- INCDMTM - Bucharest designed and realized in original solutions networks of cobotic mechatronic and cyber-mixmechatronic platforms, as follows:

1) technological platform / robot (mechatronic) system for checking the tightness of cast parts in the automotive industry;
2) technological platform / robot (system) mechatronic dimensional control with probes;
3) technological platform / mechatronic robot (system) for dimensional control;
4) 4D intelligent mechatronic technology platform / robot (system).

Each cobot technology platform (system) intelligent mechatronic robot has a standardized structure based on intelligent mechatronic platform / robot (system), cyberspace (INTERNET / INTRANET) and remote monitoring centre.

The data flow, collected and transformed, is sent through the communication bus, to the beneficiary or supplier for monitoring the processes carried out at quality levels in accordance with European and / or international norms and standards, through the remote monitoring and remote configuration centre.

The Cobot network of cobot technological platforms / mechatronic robots (systems) ensures the collaboration with the network operator, respectively with the computer / server through specialized software and the Internet and / or Intranet.

Depending on the structure of the network, collaboration is ensured for the development of all services related to specialized fields.

The Cobot network of cobot platforms / systems (robots) is intended for the development of the digital enterprise and the intelligent industry (4.0), while ensuring the modernization and development of specialized smart fields: the intelligent car industry (mechatronized); mechatronics and cyber-mixmechatronics industry; advanced aeronautical industry; intelligent naval industry; advanced railway industry; smart medical industry; etc.

The Cobot network of cobot / robot platforms (systems) develops around it, a network of groups of innovative SMEs with intelligent specialized fields. Every SME in Romania or in the EU based on the integration and implementation of cobotic technological platforms for intelligent electronic control and industrial technological platforms will go through steps and stages of development to digitize all technical-technological activities. -economic-logistics, etc., respectively as a digital enterprise and so on, as a smart industry (4.0), respectively as a computerized society.

Each SME, thus transformed, will have a digitized structure, will have a staff trained in digitization processes for all types of activities carried out at all levels and will have a management adaptive to the level of development of society.

Depending on the applications of the Cobotic Network and the applications of the COBOT Platform, all the activities of

the Network, for their integration in each SME-member component of the network, respectively of the platform, in order to become in time, a digitalized SME and contributor to the development of Smart Industry 4.0 related to the SME field.

The integration of Cobotic Networks and COBOT-type Platforms, from the SME level, to the groups / clusters of specialized smart domains, will contribute to the development of digital enterprises and Smart Industry (4.0).

IV. The Smart Solutions for Digital Enterprise and Industry 4.0

Romania's vision establishes a set of principles of action, based on 3 main pillars:

- Pillar 1, regional assertion, global assertion: companies become key operators of innovation and smart specializations, for the digital enterprise, the smart industry (4.0), the smart economy and the computerized society;
- Pillar 2, excellence through internationalization: the RDI sector as a space of opportunity and support for the digitized enterprise at international level, for the smart economy, for the computerized society;
- Pillar 3, regional leadership at the frontier of science and technology: breakthroughs in strategic areas such as Industry 4.0, smart economy and computerized and post-computerized society.

(a) Advanced Concepts for Industry 4.0

(b) The concept of "Industry 4.0 Circle of Activities" (Fig. 5)

Fig. 5. Illustration of the concept "Industry 4.0 Circle of Activities."

Fig. 6 shows the concept "Cube of Activities in Industry 4.0"

The structure of the architecture of the activity cube, includes the chain: physical level - Creation, Actuation, Communications Sensor data and digital level - bus data, Data Fusion, Analogies, Digital Decision, Specialized Software.

Fig. 8 shows the connection between the physical level and the Cyber-Computerized digital level of Enterprise 4.0. Thus, data analysis with specialized software provides a perspective on how data from smart sensors are used, data flowing through specialized data buses and communications networks, making possible the connection between the physical and computer level. data allow the development of products and at the same time allow companies to expand their services and better align their offerings with customer needs.

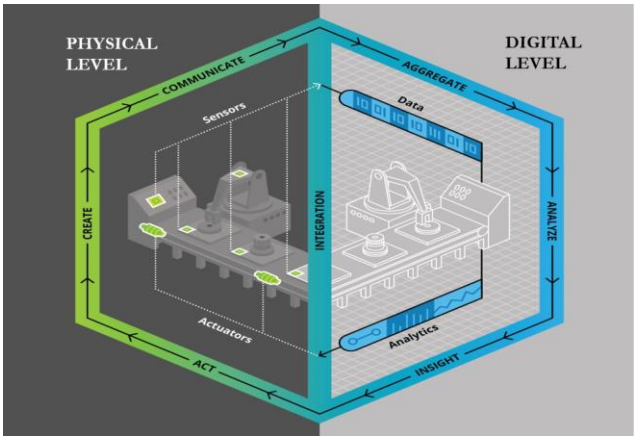

Fig. 6. Illustration of the concept "Cube of Activities in Industry 4.0"

The Interconnected equipment can include computer systems (desktop or laptop) or peripheral equipment (printers, scanners, etc.). Connectivity is provided by network equipment (hubs, switches, routers, wireless access points). Data transmission is achieved through transmission media that can be:

- copper conductors - for data transmission in the form of electrical signals;
- optical fibre - made of glass fibres or plastics - to carry data in the form of light pulses;
- wireless data transmission media - transmit data in the form of radio waves, microwaves, infrared or laser beams - in wireless connections;

(c) The concept of "Horizontal and vertical link on the value chain in Industry 4.0".

Fig. 7 shows the concept of "Horizontal and vertical link on the value chain in Industry 4.0".

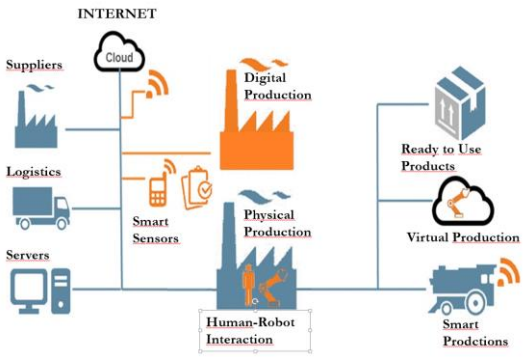

Fig. 7. Illustration of the concept "Horizontal and vertical link on the value chain in Industry 4.0".

The structure of the architecture for the horizontal and vertical connection on the value chain in Industry 4.0, includes the following chain: Suppliers - Logistics - Servers - Internet (Cloud) - Intelligent Sensors - Human Interaction - Robots - Physical Production - Digitized Production - Intelligent Products - Virtual Production - Finished Products.

Fig. 7 shows the simplified horizontal and vertical link on the value chain within Industry 4.0. This means that, on the one hand, companies need to better integrate and digitize their vertical data flow, from product and procurement

development to processing and transport logistics, and on the other hand, it requires horizontal collaboration. with key suppliers, customers and other partners in the value chain, for example using product identification and monitoring solutions. For companies, these aspects involve the creation of complex digital solutions. In addition, companies develop new products and services with digital features, which cover the entire product life cycle and therefore facilitate closer contact with end consumers.

Companies also invest in digital services and create complete solutions tailored to their customers' ecosystem, often in collaboration with value chain partners.

(d) The concept of "Simplified Scheme for Auto Digitized Factory"

Fig. 8 shows the concept of the simplified scheme for the digitized car factory.

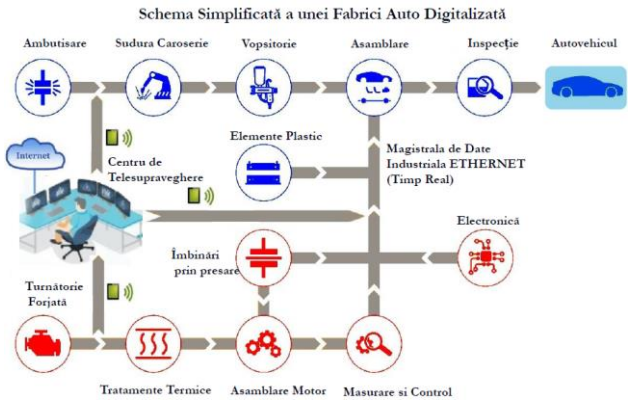

Fig. 8. A simplified scheme for the digitized car factory.

The architectural structure of the concept of the simplified scheme for the digitized car factory includes the following matrix chain: stamping - body welding - painting - assembly - inspection - Internet Remote monitoring centre - plastic elements - Ethernet industrial data bus (real time) - forged foundry - press joints electronics - heat treatment - engine assembly - measurement and control - vehicle.

According to figure 8, the Simplified Scheme of a Digitized Auto Factory is presented. Digitization and data management are increasingly used in the production process of machines. After completing and testing each machine, about 2,300 parameters are obtained. Any parameter fluctuation is quickly detected and interpreted.

The most vulnerable jobs are routine-based ones, which require a lot of standardized tasks (working on the assembly line), and that are repetitive. These routine jobs, generally of medium qualification, have been decimated by the technological revolution and digitalization but the number of specialized employees has increased. Such jobs are usually found on assembly lines in a car factory. Routine tasks that can be reduced to well-defined algorithms have been digitized and computerized, and in some cases have been outsourced via the Internet to much cheaper labour markets.

(e) The concept of the "Simplified Scheme for the Digitized Power Plant"

Fig. 9 shows the concept of a simplified scheme for the digitized power plant.

According to the mentioned figure, the architectural structure of the simplified scheme concept for the digitized power plant, includes the matrix chain: biomass energy - nuclear energy - thermal energy - solar energy - wind energy - hydroelectric energy - communications - Internet - Communications - distribution station - energy storage centre - car charging centre - electric - industrial platform - smart homes - smart city.

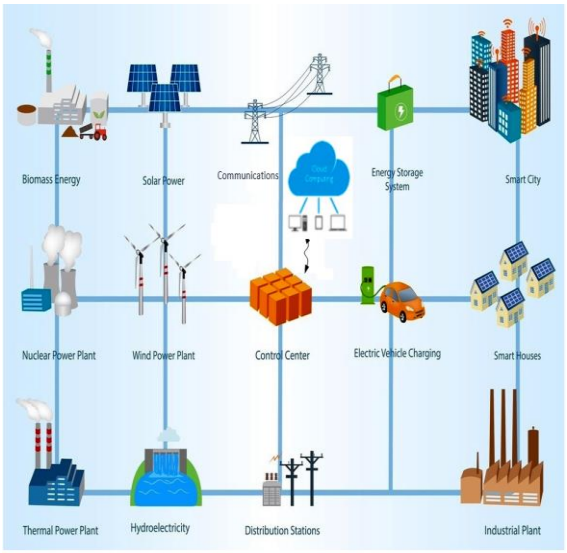

Fig. 9. A simplified scheme for the digitized power plant.

The figure shows the Simplified Structure of a Concern of Digitized Power Plants. The scheme of global interconnection through a Remote Monitoring and Telecontrol Centre of all energy suppliers obtained by different methods is presented: wind, thermal, solar, hydro, etc.

Energy security, universal access to affordable energy services, energy production and supply to consumers are one of the biggest challenges facing the implementation of digitalization in this sector.

(f) The concept of the "Technologies related to Industry 4.0 (Fig. 10)"

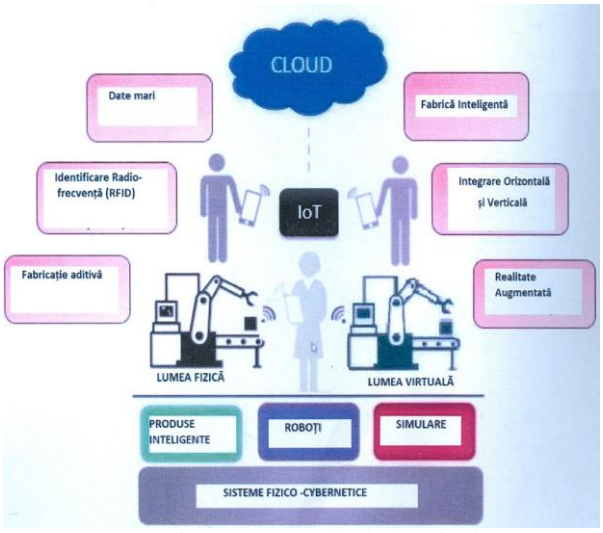

Fig. 10. Illustration of the concept "Technologies related to Industry 4.0

V. Conclusion

In brief, we intend a definition of Smart Industry (4.0):

- industry 4.0 is not a revolutionary generation 4.0 industry, but an evolutionary improvement of the production and business model;
- industry 4.0 - consolidation of the industrial policy paradigm;

- industry 4.0 - opportunities and risks in the economy and society, -productivity and competitiveness; -employment development; - qualification; - big data / data security;
- industry 4.0 - revolutionary idea, evolutionary implementation;
- industry 4.0 - political initiatives and actors;

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

IS conducted the research, contributed at identification of the cooperation of the economic environment with research for increasing innovation in digital enterprises in Romania and the smart solutions for Digital Enterprise and Industry 4.0 and written some part of the paper.

GG centralized the results of research and contributions on mechatronic and cyber-mixmechatronic systems, technology platforms, cobotic platforms for the Digital Enterprise and written some part of the paper.

All authors had approved the final version.

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