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CYBER STRUCTURES FOR NETWORK PRODUCTION SYSTEMS

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Abstract: Production systems are faced with the challenges of developing an increasingly demanding products and services that must be at the will of the purchaser and in the shortest possible time, at any place and at a competitive price with enormously high level of quality. Globalization and erasing borders brings new market opportunities, potential and challenges that require different characteristics of production systems. Production systems are now coming to grips with a wide range of management competence, the structural independence and communication in order to achieve competitiveness. Achieving competitiveness of the production system in the future will depend primarily on their ability of rapid integration into distributed production systems, intended for the production of high-demand products. Such distributed production systems require a production system that interacts with various external systems, such as subcontractors, supply chains, logistics, transport services, maintenance services etc. For such demands production systems must be able to integrate into the network of production systems, which aim to take advantage of that connectivity.
This paper provides an overview of cyber structure of production systems that enable the integration of the production system in the production network, thus enabling achievement, competitiveness in the global manufacturing environment.
Key words: autonomous work system, elementary work system, cyber-physical production system, information-communication technology, network production system

1. INTRODUCTION

Production systems (PS) are faced with the challenges of development of increasingly demanding products and services with changing prices and with an enormously high level of quality. Globalization and erasing of market borders must be the will of the purchaser and the shortest possible time, at any place. Such trading emporium brings new possibilities, potentials and challenges that require different characteristics of production systems. Today, with globalization, increasing competitiveness of the production system and the rapid development of science and information and communication technologies (ICT), new opportunities for successful exploitation of complex distributed production systems as opening up.
Production systems are the basis of the most economically developed countries in the world. It consists of a set of elements, such as materials, tools, machinery and equipment and also operating funds and entities to decide and set different work processes. In addition to these elements there is a wide number of additional functions in the production systems to interact with a wide environment, marketing and sales through to production management systems. The effect of PS is intensely connected with the environment, consisting of sub-contractors, logistics systems, service providers, suppliers, financial institutions and many others. The level of interaction and their dynamics in the past twenty years, with the introduction of ICT in production is sharply increasing and intensifying. The behavior of the system is influenced by various factors of its environment, through constantly changing requirements, smaller series of products, increasing variability, constant increase of information, the presence of competition, the degree of parallel activities, demanding coordination and communication. On the other hand production systems affect its activities, products and services on the environment, which undoubtedly leads to changes in the environment.
This mutual dependence requires a comprehensive study of the relationship of all related elements to adequately understand the behavior of the production system. This requires systematic approach to structuring, modeling and management of production systems. The state of today's organizational structure, managerial and organizational processes, technologies, tools and management have reached a level at which they are unable to follow the requirements of the modern, global marketplace. This requires a greater focus of companies towards their core competencies on one strain, and opening and participation with other companies through a network

connection in distributed environments, on the other. The work in distributed environments today is bridgeable problem thanks to the development of ICT and the Internet. On this basis, the necessary structures have been changes in the organization of production systems and a high level of participation in the network production systems (NPS).
Achieving competitiveness of the production system in the future will depend on their ability to quickly integrate the distributed production systemic, intended for making high performance products. Efficient construction of such a system is possible on the basis of appropriate methods for structuring and implementation of information and communication infrastructure to participate in a distributed environment.
In this paper it is presented the possibility of including production systems into network production systems from the point of view of cyber structure. The second chapter presents the technologies that enable such cyber-structuring. The third chapter presents the relevant concepts of cyber structures able to work in a network environment, their building block and functional units. In the final part of the paper, the guidelines for the future development of cyber structure of advanced production system capable to meet the demands of the global market.

2. MODERN COMMUNICATION TECHNOLOGY TO CYBER STRUCTURE OF PRODUCTION SYSTEMS STRUCTURED

Deleting market boundaries, the emergence of the internet and the development of communication technologies have created preconditions for the development of new structures of production systems, such as distributed adaptive production systems, production networks and autonomous production systems. Due to the development of such production systems, consequently realized unlimited number of communication interactions between participants in the production system, which such production systems become unpredictable, their behavior is more complex and managing is more difficultly. Today's complex production systems are composed of many elements that are trying to achieve mutual communication, interaction and production activities. Elements of complex production systems are not only real, physical elements, such as machinery, tools and similar, but there are also digital communication elements, such as the Internet, a variety of communication networks, protocols, files, computer control devices, robots, mechatronic systems and many others.

3. INFORMATION - COMMUNICATION TECHNOLOGIES AND INTERNET

Information and knowledge are two basic resources for successful business. For quality decision making is necessary to know the different types of information on the operations of the company and of its surroundings, such as the availability of equipment, its potential opportunities, information about the participants in the network, its competitors, but also the sociological aspect which is important element of any production system. For the fast and high quality collection and storage of such information, and their effectively research and use in the methods and models that enable better decision making, it is necessary to implementation of the information – communication technologies in the field of production systems. Information–communication technology represents connection of microelectronics, computers, telecommunications and software, which allows input, processing and distribution of information.
Communication technologies are the media for relaying information between participants of communication. In modern communication dominate electronic media, due to the possibility to quickly and easily establish a connection with physically remote participants, relatively low cost of sending information, and integration of information systems in the field of electronic business. These media can be interpersonal and mass. The media that has the characteristics of both is the Internet.
The internet is characterized by robustness and reliability, quality of service, scalability and standardization. Thanks to the Internet, today we have developed a smart environment, in the form of smart things and services, and social networks that operate in the sphere of cyber world, and which are capable of communicating in order to achieve common goals.
Internet of Things (IoT) is a concept and a paradigm that considers pervasive presence in the environment of a variety of things/objects that through wireless and wired connections and unique addressing schemes are able to interact with each other and cooperate with other things/objects to create new applications/services and reach common goals. In this context the research and development challenges to create a smart world are enormous. A world where the real, digital and the virtual are converging to create smart environments that make energy, transport, cities and many other areas more intelligent. The goal of the Internet of Things is to enable things to be connected anytime, anyplace, with anything and anyone ideally using any path/network and any service.
The Internet of Things is a novel paradigm that is

rapidly gaining ground in the scenario of modern wireless telecommunications. The basic idea of this concept is the pervasive presence around us of a variety of things or objects – such as Radio – Frequency Identification (RFID) tags, sensors, actuators, mobile phones, etc. – Which, through unique addressing schemes, are able to interact with each other and cooperate with their neighbors to reach common goals, [1].

Internet of things or smart things are active participants in the business, information and social process in which they can communicate with each other and with the environment exchange information and receive information from the senses the environment and independently react to the events and influences by running processes that initiate actions and provide services with or without direct intervention of man, [2].

The internet does not only integrate the things and services but its role can be found in the integration of business processes, production and social networks. Thus, the Internet [3] represents a worldwide network of interconnected and uniform addressed facilities and services for communication via standard protocols.

In the field of industrial process Internet has contributed to the creation of smart environments representing the main factor of integration in a production environment that makes possible to link the physical and cyber system elements, building a smart systems on that way. Such systems lead to the creation of smart factories that represent the factory in real time, [4].

The evolution of the global economy can be characterized through ever shorter life cycles for products and services while, at the same time, development costs increase and the time to bring a new idea into the market reduces, [5]. In the struggle to be innovative and competitive in the market, new products and solutions are increasingly developed in collaborative settings within value networks or entire value chains that involve more than one company or institution [6]. Collaboration has introduced itself as a promising approach to address various challenges enterprises are faced with in a knowledge driven society, [7].

The basic idea of the Internet of Services is to systematically use the Internet for new ways of value creation in the services sector. There are different angles from which one may look at this approach. From an IT perspective, service oriented architectures, software – as – a service, as well as business process outsourcing are related trends. In this context, the concept of service is referring to a technical understanding of software functions provided as Web services. But services in a broader sense are more than technical capabilities that can be invoked by computer program interfaces. A service is a commercial transaction where one party grants temporary access to the resources of another party in order to perform a pre – scribed function and a related benefit. Resources may be human workforce and skills, technical systems, information, consumables, land and others, [8].

The internet does not only integrate the things and services but its role can be found in the integration of business processes, as well as in supporting production and social networks. Thus, the Internet [3] represents a worldwide network of interconnected and uniform addressed facilities and services for communication via standard protocols.

Social networking is the practice of expanding the number of one's business and/or social contacts by making connections through individuals. While social networking has gone on almost as long as societies themselves have existed, the unparalleled potential of the Internet to promote such connections is only now being fully recognized and exploited, through Web-based groups established for that purpose. Web – based services that allow individuals to (1) construct a public or semi-public profile within a bounded system, (2) articulate a list of other users with whom they share a connections, and (3) view and traverse their list of connections and those made by others within the system, [9].

3. CONCEPTS OF CYBER STRUCTURE NETWORK PRODUCTION SYSTEMS

Every day in practical life we meet with working systems and technologies, which operate alone or with other various work processes in a wide range of human activities. The technology and systems used for the production of new material goods have a special role in this respect, and therefore they have more value.

Structuring and management of such work systems, which includes, subject or group of subjects, is very difficult, because it is valid for complex systems without formal mathematical description of their properties. For classical theory of management of such facilities there is no specific result, [10]. More concrete results emerge from cybernetics as the science of optimal management of complex dynamic systems, to machines as living beings, social systems and many other complex systems.

The production system is a complex structure, which is composed of a set of interrelated elements, such as raw materials, work pieces, tools, machinery and equipment or work tools, operators, entities that decide and production processes [10], which are able to perform reproducible operations of transformation of materials to achieve the desired shape or assembly operations.

In the last twenty years several concepts and approaches to the production system have developed. A comprehensive overview of these concepts is given in [11] and [12]. Despite the different approaches all these

concepts have some common characteristics: decentralized decision-making, recursive architecture between the whole and its parts. Parts of the system are autonomous units with cooperative and intelligent behavior, adaptation to changes of environment, coordination, flexible and reconfigurable organizational structure, self-organization and learning.
In the literature [13], [14], [15] [16], [17], [18] different concepts of structuring the production system are presented.

4. STRUCTURING OF THE PRODUCTION SYSTEM

Structuring presents making the structure of the production system. Production systems are integrated within the structure of the production company. Production company is a complex system, a fixed structure which is decorated with three important levels, Figure 1.
The first level is the level of business in which the lead of the company brings production policies and strategies. The second is the management level, which connects the first and third level. Leadership Rank has the task of management, development, sales and marketing. Third, the production level is the level of provided information, materials and energy, and has the primary task of the transformation of materials, information and energy in order to obtain a new product or service. All three levels are connected to each other via an information system that enables the flow of information, [19].

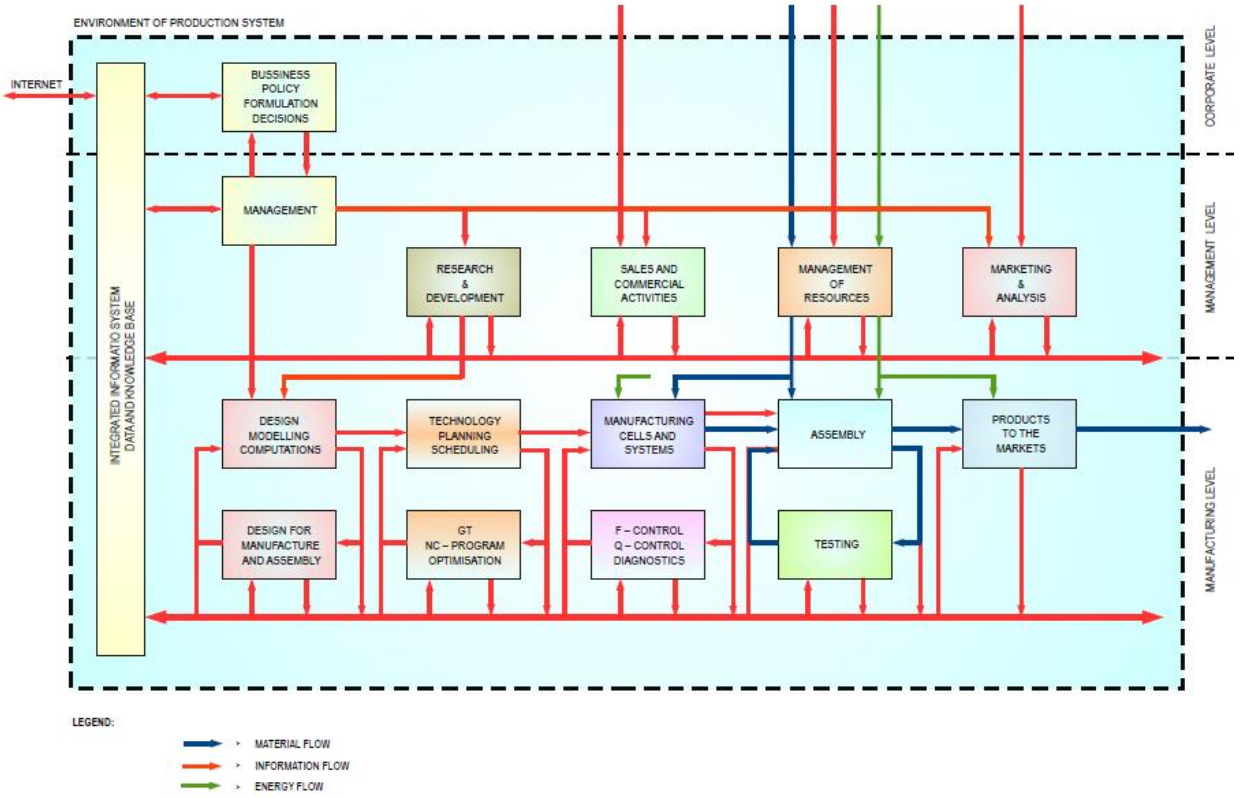

Fig.1. Production company as a complex multi-level system [19]

The production system shown in Fig. 2 is a simple scheme, which shows the essential elements for the operation of the production system. The material enters the system, it is processed by using the tools, machines and labor force. For transformation of materials into the final product requires energy. Output of the manufacturing system is products and waste material.

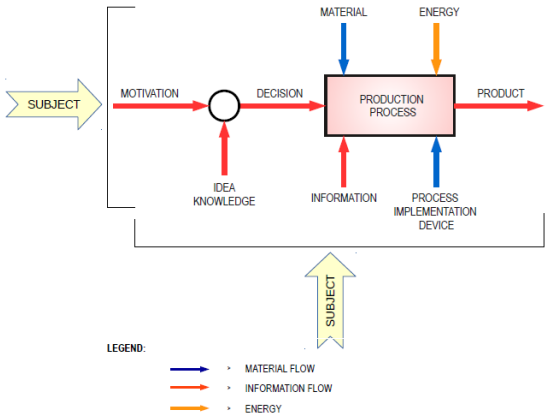

Fig. 2. Production system as a system for the transformation of material into the product (remake by Koren, 2010)

In the production system, production processes take place implementing subsystems of the production system. Basically, it is possible to perform, for each production process a simple structure operating system. On the basis of these claims basic building blocks of each production system are structured in the form of elementary work system (EWS), [16].
Evolutionary development and introduction of modern information and communication technologies and the Internet in the domain of production systems were developing new structural elements of the basic building blocks of the production system in the form of a virtual work system (VWS) [17] and elementary socio-cyber-physical work system (ESCPWS) [21].
EWS is the main contractor of the production system. His cybernetic model shown in Fig. 3. EWS consists of process, device implementation process (PID) and the subject. The process of entering the value of X is converted into the output value Y, the relation is described by the operator Gp. The concept of elementary working system is applied in all production systems and beyond. EWS is clearly defined as the basic elements of the production system, without which it cannot do the job: the process with input and output parameters, PID, body and environment. It should be noted that the role of subject in EWS is clearly defined, which separates it from other concepts in the literature. Through the subject clerk deliveries targets system and thereby give meaning to his work.

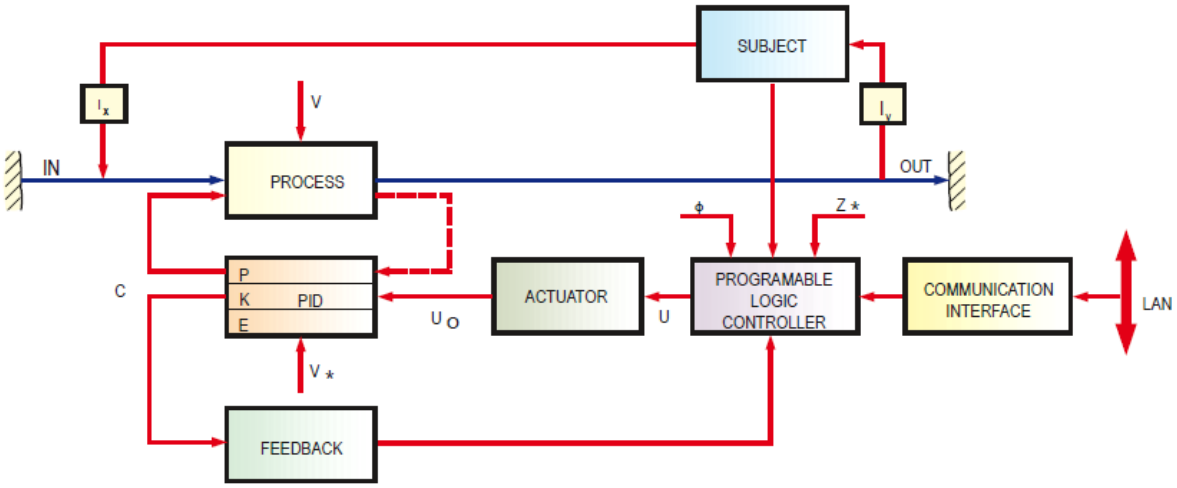

Fig.3. Elementary work system [16]

The concept of the EWS is also important from the standpoint of managing the structural complexity of the production systems. The EWS is the lowest possible composition capable of doing the job. If any part was exempted from EWS, transforming inputs into outputs is no longer possible. In addition, further division of elements does not make sense because they increase the volume. If, for example PID is divided into its component parts it will lose the generic model and increase the number of input and output signals, [22].
VWS is an abstract resource profiles presenting EWS with the relevant data and multi-agent system. VWS autonomously decide on the acceptance of the job queue and has the ability to make decisions within their jurisdiction. Analog as well as the EWS, subject plays an important role in VWs and solving tasks. VWS structure is shown in Fig. 4.
In addition to basic functional elements of the agent, i.e. Preceptor, evaluator, and effective mechanisms of reasoning, a constitutive element of VWS is a modular data & knowledge base (D & K base). Its task is to support decision-making and coordination with other agents. This allows the EWS connection with information on technological capabilities and limitations, current state, recorded the history of the event, awarded the task schedule, offers and options, etc., EWS and VWS are connected to each other via the interface. VWS is updated mapping the current state of the EWS.
The concept of structuring elementary socio-cyber-physical work system (ESCPWS) results from previous researches and set of concepts EWS and VWS. To structure a new concept, it served a generic basis virtual working system. Such a system it is possible to restructure the ESCPWS (Fig. 5) due to the extremely rapid development of intelligent technologies that we introduce in the daily production systems.
This operating system that we have shown in Fig. 5 consists of three major sections:
-The physical system as a work system (PWS) (machining the center or more of them, positioning systems, automated clamping kits, measuring systems etc.);
-Cyberspace (abstract) system, which basically consists of agent systems (control systems, equipment, coordination of sensor systems etc.);
-The social system in which there are workers, operators who manage and supervise the work of the production system as a whole.

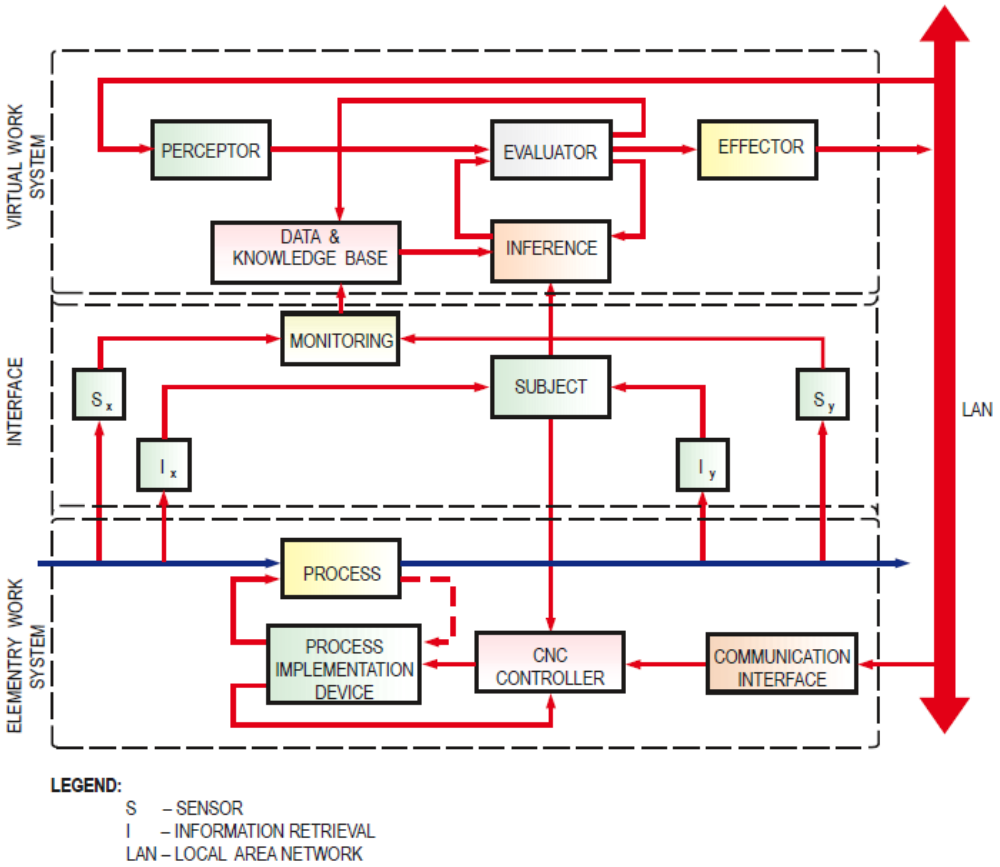

Fig.4. Virtual work system, [17]

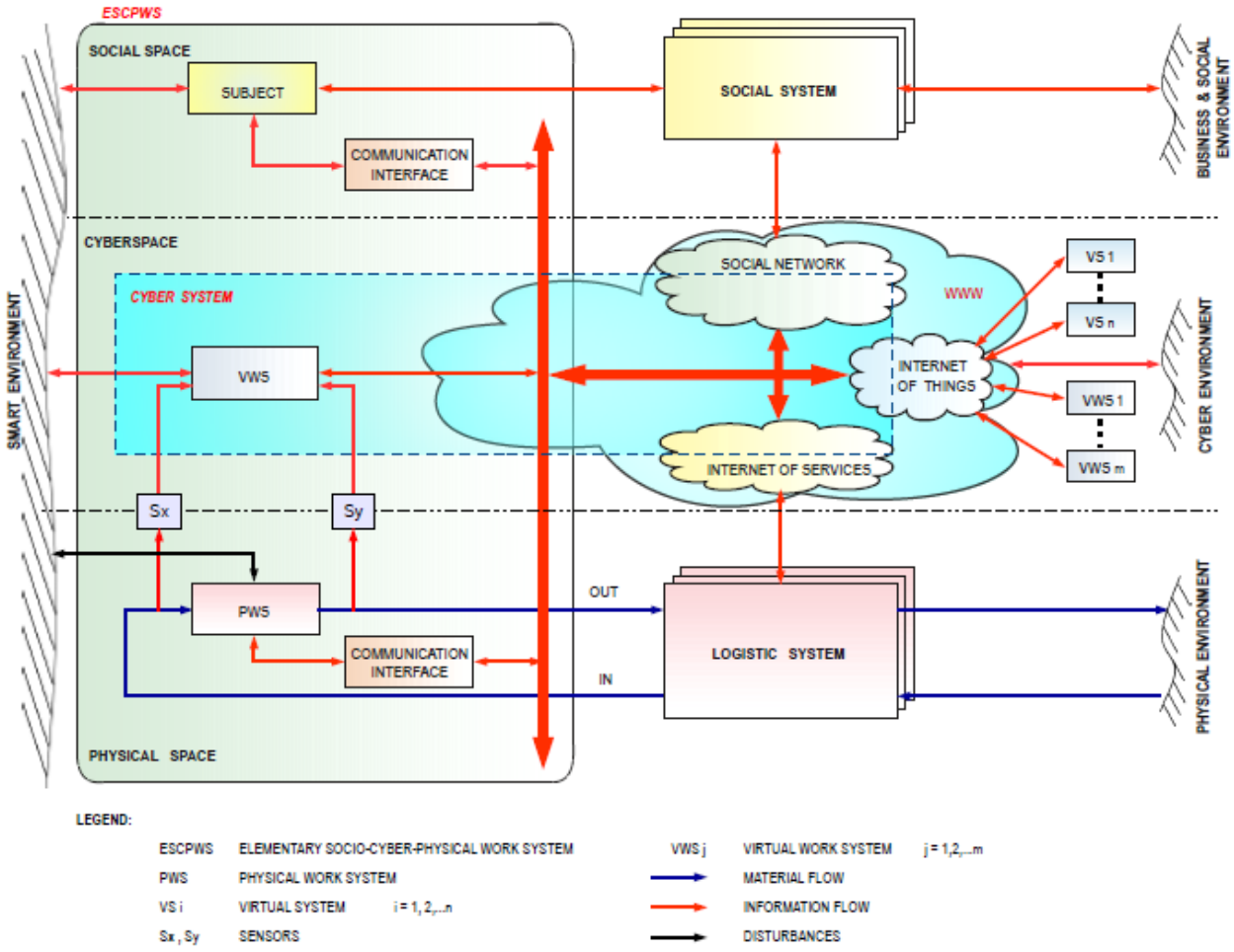

Fig. 5. Elementary socio-cyber-physical work system, [21]

The physical system is a functional unit that consists of a process device for carrying out the process (PID), the controller and the communication interface via which connects the other two components ESCPWS. The communication interface that connects the physical and cyber component ESCPWS has a role mapping condition PWS, while intelligent communication interface has a role of linking the human component ESCPWS with the other two components of the new system. Physical system is a system of actuators and sensors, making it the smart system, which enables it to communicate with the cyber world. Cyber world make the agents through which the management, monitoring and control processes that occur in the physical system. In cyberspace, creates a platform for multi-agent systems have the task, [23]:

•Configuration physical system that allows re-configurability of the physical system,

•Planners and coordinators of activities of the physical system,

•Intelligent interface that realize the connection between cyber and human world on one hand, and cyber and physical world on the other.

The sociological component of the new concept of the system is a new addition to the concept cyber – physical work systems (CPWS) and requires the need for more comprehensive elaboration and describing. For a description of the role of the subject in SCPWS it is necessary to establish initial views on the theory of socio - technical system which has occupied its place in every original concept.

5. NETWORK PRODUCTION SYSTEMS

Network production systems (NPS) represent the network-related production systems that wish to take advantage of linking and presentation in the form of larger wholes. The importance of networks is that its building blocks retain autonomous decision-making, and the coordination of the network achieves a competitive advantage. NPS is based on an application from the environment and form by highly competent partners, based on the need for a rapid response to any demand of the global market. With this kind of a network, production systems are viewed as a new complex system, [24]. These types of network organizations, open a new opportunities for competitiveness, innovation, agility and adaptability in a production environment, which is based on communication between partners, and exchange of information, knowledge, resources, competence, based on mutual understanding, participation and collaboration.

Network connection of production systems raises many issues in terms of collaborative work, exchange and storage of information, synchronized operation, decision-making and consultation.

6. CONCEPT OF CYBER STRUCTURE OF NETWORK PRODUCTION SYSTEM

The concept of complex adaptive manufacturing systems (CAMS) [16] describes the production system as complex adaptive manufacturing system, structured as a network of a large number of building blocks. Brassieres acting in parallel or one after the other and build a network with interactions. CAMS provides constantly changing widget production system. The production system is constantly adapting to changes.

The concept of adaptive distributed manufacturing system (ADAMS) [17] has been developed based on the concept of CAMS. Identical to the concept CAMS concept ADMS defines production systems as building blocks for networks that are distributed. Based on this production system builder are not directly EWS, more autonomous work systems (AWS) [25], where each autonomous operating system contains in its structure one or more EWS. Structuring the production system takes place dynamically, due to connectivity AWS in a production network. Figure 6 shows a conceptual framework for ADMS.

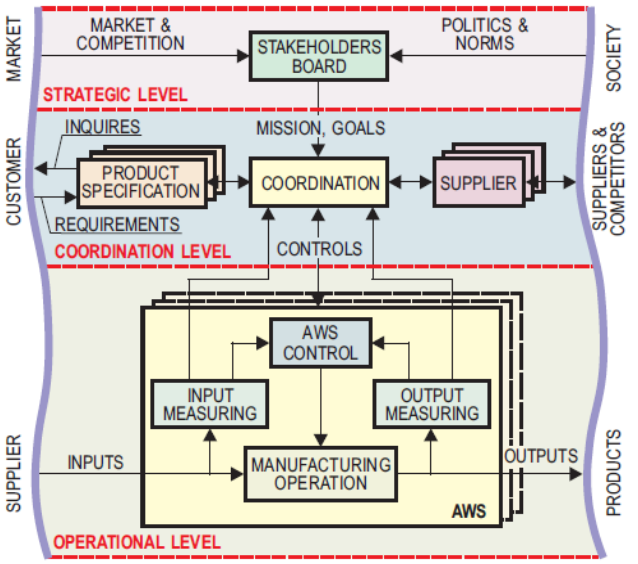

Fig.6. ADMS conceptual framework, [26]

The lowest level in a defined concept ADMS presents the operational level, or, the level of operating activity, which exist heterogenic redundant and autonomous work systems (AWS).

AWS is defined as a system with a complete technological functionality and a corresponding management, [25]. The technological functionality is basically constructed as of elementary work system, which by definition [16], make the process and the device for implementing the process and the subject (e.g. the operator). The elements are structured in two indoor and one outdoor control loop. The structure of autonomous working system is given in Fig.7.

The first internal control loop enables to control operations in real time. The second control loop enables management system based on the parameters that measure critical dimensions, carried out on the basis of information on events and situations of elementary operating system, and is used for high-quality decision-making in the context of resource management. The outer loop takes place at the level of coordination where in the feedback that is the basis for effective decision-making at the level of coordination and efficient operation of AWS.

The basic structure of autonomous work system also includes a local data & knowledge base in the local network. Control loop and the data & knowledge base form an independent information system AWS, which corresponds to the system for execution of production (Manufacturing Execution System - MES) and allows autonomy AWS as well as communication with other systems in the network.

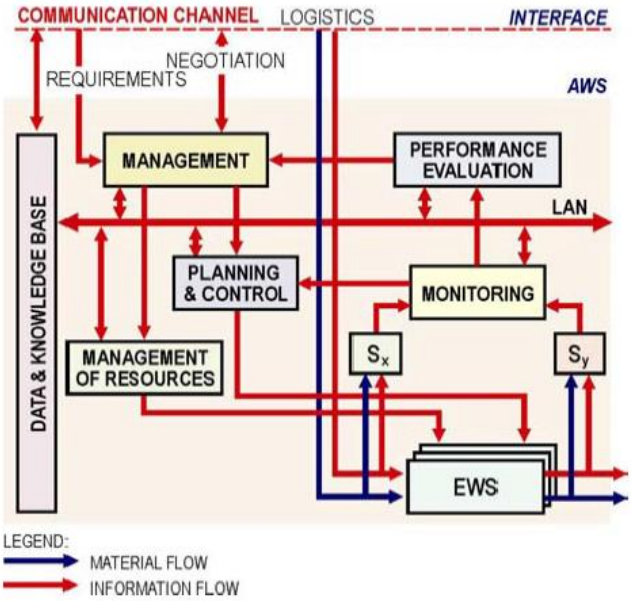

Fig. 7. AWS structure [25]

The concept of a learning self-autonomous working system (SL.AWS) [27], is defined by studying the functionality of AWS, enabling the adaptation of AWS in production networks. Fig. 8 shows the structure SL.AWS.

Structure SL.AWS except AWS basic structure, which is set in the control loop and a real time performance management loop, the loop has to learn, which is added on top of the structure.

Loop for learning is based on the database where the data which were collected in the loop in real time during production operations are stored. The database contains information on the processes (process parameters), resources (human subjects, tools, etc.), Work pieces (parametric quality input material and output components), operations (work orders, quantity, productivity, maturity, etc.) and the environment (air temperature, relative humidity and pressure, pollution, dust, noise, lighting, etc.). This database is input to data mining. The results of data-mining are used to present knowledge.

The new found knowledge then stores the model in the form of knowledge in the knowledge base and managed for future use. New knowledge can be used for adaptive management process as well as an interactive decision support during the process of planning and operations, procedures, installation, quality management, forecasting failures, defects diagnostics, and maintenance planning, and the like. It may also be used for detection of hidden relationships (for example, between the process parameters and the quality of the environment), which can then contribute to a better understanding of the process.

By using ICT and the Internet in the domain of network production system enabled cybernetics AWS and creating a new concept based on ESCPWS as basic widget. Evolutionary process AWS is structured as an autonomous socio-cyber-physical work system (ASCPWS) [21], Fig. 9.

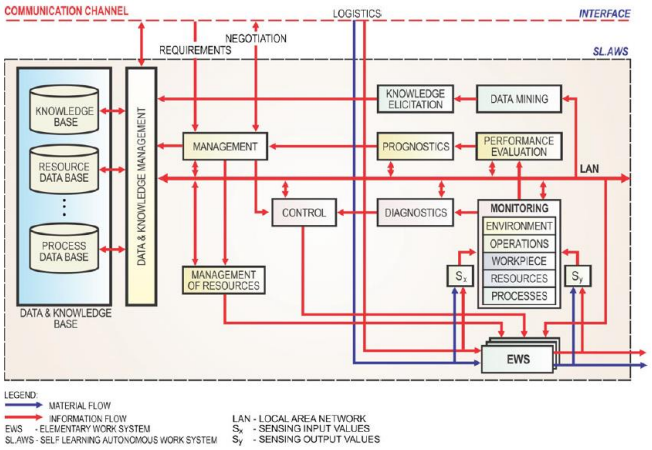

Fig. 8. Model of a self-learning autonomous work system (SL.AWS) [27]

ASCPWS are built from three basic building blocks, namely: social element that integrates the subject, cyber element which represents a virtual autonomous work system (VAWS) as a virtual element AWS and physical element which includes PWS. These building blocks achieve mutually communicate. To connect social elements and elements involving physical world in the network and their communication with the elements of cyber system is necessary to the existence of appropriate communication interface. The subject is the interaction with other elements of the social environment, VAWS communicates with the elements contained in the cyber system, while elements of the physical environment in the form of PWS interconnected information and communication and material flow.

7. THE CONCEPT OF SERVICE NETWORK

Services are today facing the various areas of daily life, such as health services, financial advisory services, repairs cars and the like. In the area of production in the last few years intensive develop systematic approaches to structuring and implementation services. Some of the most important approaches are defined in the work [28], [29].

Service is generally perceived as an activity [30]. This means that service cannot be stored as opposed to materials and it disappears instantly. Definition of service certain items, including service channel to deliver and amplify services and service contents to be delivered. Usually, artifacts play roles of service channels or service contents.

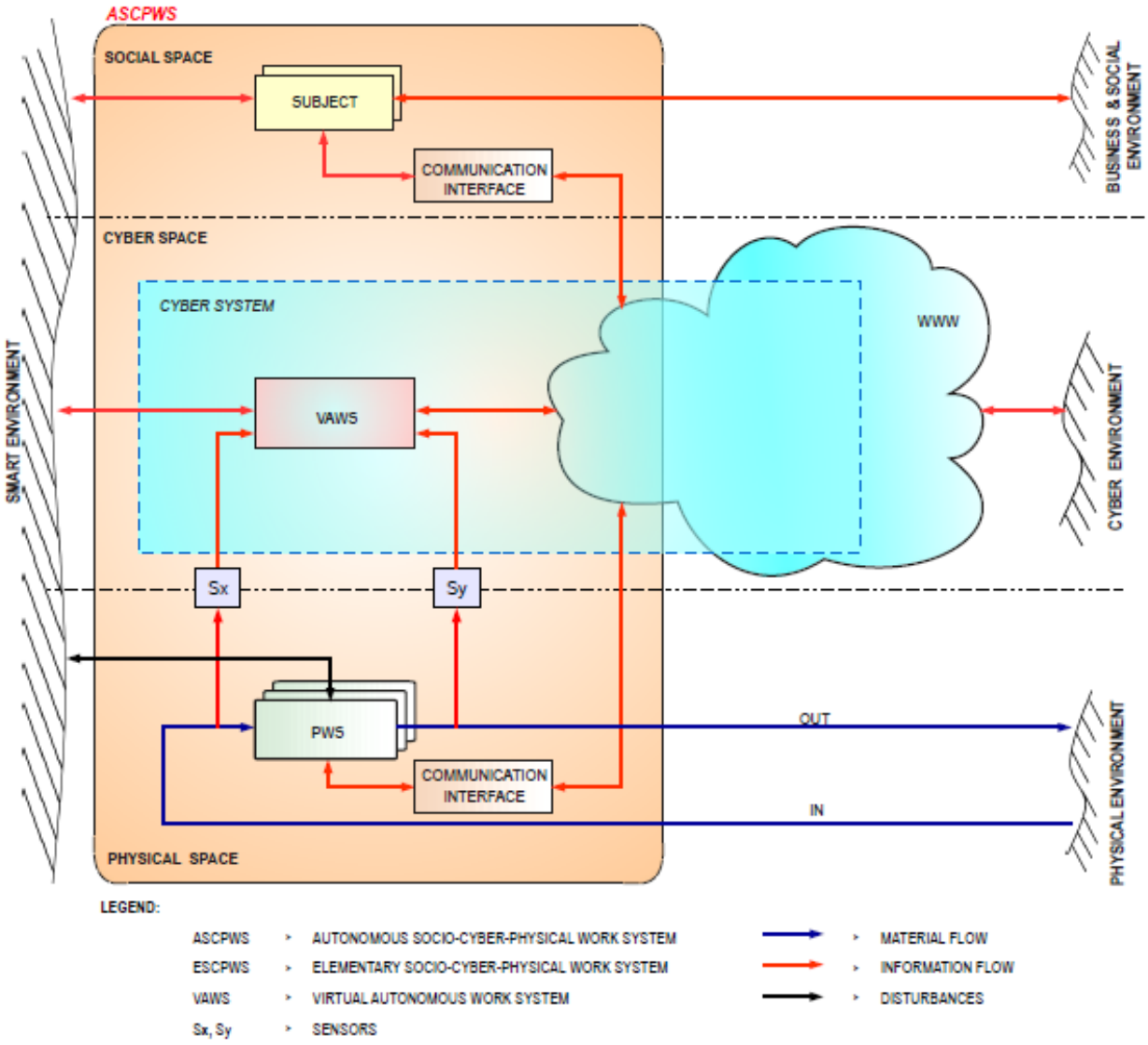

Fig. 9. Model of an autonomous socio-cyber-physical work system (ASCPWS), [21]

Service is a framework of artifact, service provider, service receiver, and environment. A service receiver receives service contents from a service provider through a service channel. Service contents are material, energy, and/or information. The service channel in delivering service contents consumes material, energy, and information. These imply that service cannot be free from environmental impacts. Service sent by the service provider changes the state of the service receiver, which is the most important feature of service as activity

This definition can be contrasted against, for instance, Andrade s definition of service elements, i.e., objects, procedures, and people [31]. While Brezet, et al., [32] are concerned about the distinction between service and products, they do not directly define service, but discuss the product-service system. They also categorize service into non-material services, dematerialized services, eco-efficient services, product-life-extension (services), product use services, product oriented services, need-oriented services, demand services, results-oriented services, and product based services. They also identified elements of a system in which service delivered, viz.,

device, infrastructure, and user practice, [28].
Services represent a business opportunity for various production companies. Due to the increasing saturation of the market, the advent of competition, the emergence of new, modern information and communication technology, manufacturing companies have been forced to look for new business opportunities. These options can be exercised through the concept of production and service systems (production-service system - PSS).
The concept of PSS proposes production of products, supported by services, with the aim of reducing impact on the environment [33]. PSS is defined as a set of products and services that can be sold and with them to meet the needs of the customer.
A Product Service System is a marketable set of products and services capable of jointly fulfilling a user's need. The PSS is provided by either a single company or by an alliance of companies. It can enclose products (or just one) plus additional services. It can enclose a service plus an additional product. And product and service can be equally important for the function fulfilment, [34].
In accordance with [16], the structural complexity of the production system increases, if new correlations among the builders of the system are created. In the field of PSS correlations are resulting from the integration of products and services.
AWS due to its thinness has limited functionality. For additional functionality AWS reaches for network services, network systems through integrated ICT technologies and the Internet. Viewed from the perspective of AWS using a service connection is established between the service provider and AWS, which at the moment is a beneficiary services.
The concept of a production-oriented production networks (POPN) allows sharing of certain functions within the production network by building of AWS and service units (SU) [35]. Example of a service unit is shown in Figure 10.
A service is provided during the service process, which is performed by service resources and a human subject. The service process is not necessarily performed entirely by a particular SU; the SU can also consume services that are provided by other SU. The service process is performed on a service object by changing some of the properties of that service object. The service object is the property of the service beneficiary. Moreover, during the service process, the ownership of the service object does not change. Thus, the service beneficiary is involved in the service process. The behavior of an SU is governed by two sets of controls: a set of objectives and constraints defined by the SU stakeholders and a set o rules and conventions defined by the manufacturing oriented service network (MOSeN) in which the SU operates, [35].

Fig.11 shows the MOSeN concept. An individual AWS and an individual SU can be included in several MOSeN. In addition to SU and AWS, two special units are contained in each MOSeN: a virtual competence centre (VCC), and a virtual coordination unit (VCU). The VCC and the VCU, introduced in [26], enable cooperation and coordination between AWS. Moreover, in the MOSeN, the VCC and the VCU play additional roles.
The VCC provides information about the services that are available in a particular manufacturing network, acting as a service registry, whereas the VCU is a virtually merged coordination unit that consists of various manufacturing experts who physically operate in different geographical locations.

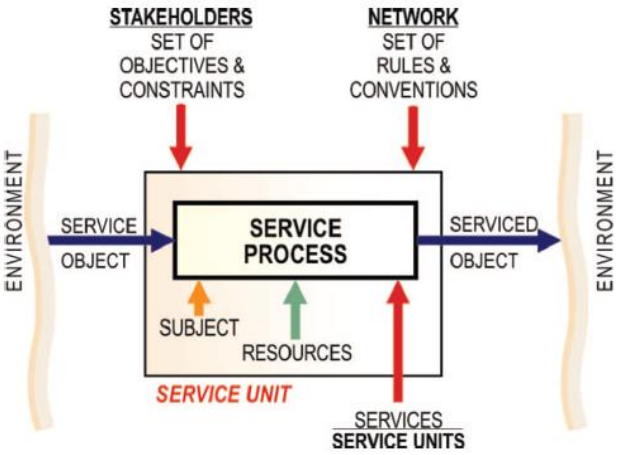

Fig.10. A functional diagram of a service unit, [35]

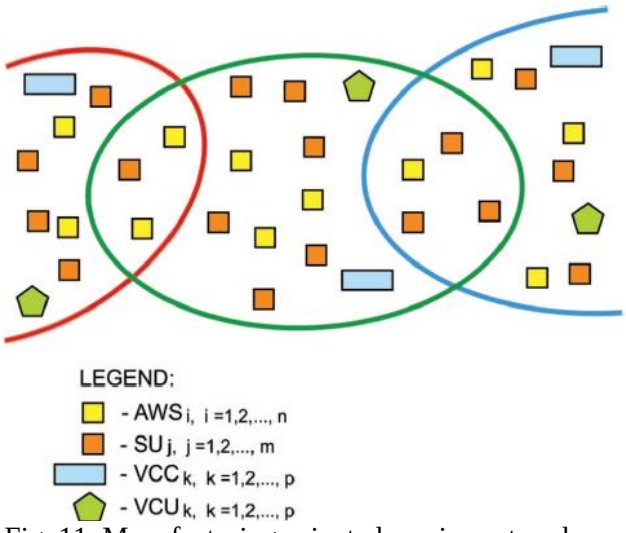

Fig. 11. Manufacturing-oriented service networks, [35]

The role of the VCU is the coordination of the processes that are within a collaborative development and the implementation of complex MOSeN, requiring heterogeneous functionalities that are not available in an individual SU. Therefore, such

MOSeN cannot be performed by individual SU. They are usually developed and implemented for a specific service beneficiary, addressing its specific problem, and they are not published in a service registry.

8. CONCLUSIONS

On the road of globalization, manufacturing companies are exposed to all the complex requirements of turbulent markets. In order to maintain its competitiveness are forced to adjust its production structure challenges of the modern world. On the basis of these challenges are being developed various structures of production for more widespread individualization of production and fulfillment of the objectives. From these fundamental principles in this paper sought to show the evolutionary path of development of production systems in terms of cyber structure of production systems. Through working closely describes the evolution of elementary work system to modern cyber-physical labor and production systems and their integration into the global, network flows and systems.

Future work must be focused towards more precise and better describe the role of the subject - a man in advanced manufacturing systems. Describe and define communication and cooperation entity with more present intelligent systems, which carries with it the coming industrial revolution or Industry 4.0

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