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What tracks for sustainable production systems in Europe?

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Abstract

The future of production systems is a big concern in Europe and particularly in France where two national initiatives were started in 2012: a specific ministry of productive recovery and a specific scientific reflexion on research on production systems. A one-year work gave the main ideas for what is significantly moving in production systems to make them sustainable for a long time in a European country. It highlighted three main evolutions that would create the industry of the future quite different to the today manufacturing industry: at first, the production systems would be pulled by the development of the technologies with high added value that emerge from today; Then it was considered that the link of the systems of production and the territories would be a heavy trend of future and thus put forward the evolutions of the organization. Finally, it could be the revival of the social contract that would pull the evolution of the systems of production. The paper relates the first conclusions of this national work.

Keywords: Production systems; Future research;

1. Introduction

As many countries in Europe, France is in trouble with its industry because of the lost of many jobs and a very bad balance of exports. This situation mainly questions the existence of production systems in France. Europe would like to see industry as a growth leader [1-4] by innovation [5]. The Manufuture initiative was created to think the future of indutry [6-8], including through industrialist round table [9].

There is in France a remarkable change of paradigm for the economic and social development of France. The concept “to Produce without factory” of the beginning of the 90s sent back the industrial production to remote and distant back office services and the science of the production to the countries of low wages workers. This vision announced short-term economic difficulties because “no production” brings rather logically “less jobs” and “not much to export”, but also in the medium term because mastering the production issues is necessary to be in position to design efficiently and finally to innovate.

We prefer today “to produce with science and innovation” that allows just as much to go towards this knowledge society which Europe wants to build. Indeed, to associate the industrial production with research and education allows to hand again the progress in the service of the society: the new challenges are in the new products and services, the new manners to work and to design and to produce. It is also a win-win posture: the industry finds a place of choice in both the economic and social development; the scientific world finds its legitimacy of scholar, capable of creating the technological and social progress alongside with the society.

The order of this research paper is thus clearly a contribution to the “reindustrialization of France by research”. It was a vast discussion about the meaning of France in this sentence because science, as well as industry, does not respect the borders. We decided to understand it “as any action which has fallout on the persons living in France” meaning that it could be generalized to everywhere in industrialized countries.

The objective of the paper is to present the industrial production system as it could be in 2030 from a French and European perspective then to derive the effort of

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research needed to go this way. It is built with a presentation of the study method and the main results from the literature in section 2. The three main scenarios of the future of production systems are then discussed in section 3. Section 4 is dedicated to a short discussion of what will really moves to guide production systems evolutions and to the conclusion.

2. Study methodology and state-of-the-art

2.1. Methodology

The study was initiated by three academic networks: AIP-PRIMECA network on the design and the manufacturing of industrial systems; GDR MACS, in particular the community of the design and controling of production; the French society of process engineering dedicated to the domain of the processes. These scientific communities appealed to all the additional expertises necessary for the understanding of the production systems: industrialists (SMEs, groups) covering numerous sectors and human and social sciences specialists of employment, work conditions, education, management, innovation and economy. All in all, a rich community of 40 experts. The study process (Fig. 1) is in three times: understanding when the expertises were shared to have a relevant and common diagnosis; imagination when the plausible scenarios of future were built; proposal when the scenarios are turned to avenues of research.

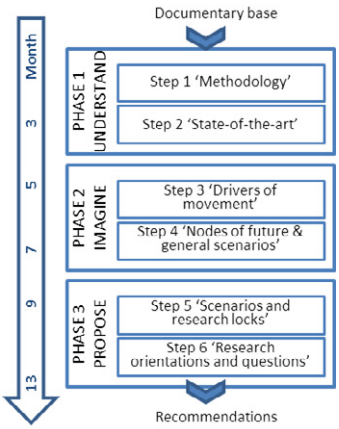

Fig. 1: Three stages study methodology

2.2. State of the art

The literature on what would be useful for industry is very rich in studies and reports and roadmaps. The question is to extract the drivers of production systems and to be free from industrial sectors. Indeed literature is very focused by region: Europe and mainly the Manufuture initiative [6-10], UK [12], Italy [13], and Germany [14] defined their view for research on production systems very recently; all these approaches were pulled by the technological point of view. USA also defined their view and still from the technologic perspective [14-6], including a special report to President Obama [18].

The second orientation was to see manufacturing as a sectorial activity and reports flowers on specific sectors [18] as logistics [19-21], chemical and process industry [22-25], energy [26-27], digital [28] and production automation [29], machines [30] and factories [31].

The main promising comes from the key enabling technologies to revolution industry by their facilities to innovate in products and production systems. Many works were carried out to analyze their potentials and to forecast the needs for an advanced manufacturing sector [32-35]. There were much less work on working conditions in industry [36-38] that means that the synthesis was difficult in this field crucial for the production systems of the future.

We came to the conclusions that the production system model could be split into five main components: C1 Technology; C2 Work; C3 Product flow and location; C4 Economy that are all internal components from the production systems point of view and CE5: Global environment that is an external component characterizing the world where production systems should live in (Fig. 2). Every component was studied to extract the main variables that could explain the evolution of production systems. The variables are summarized in Fig.2.

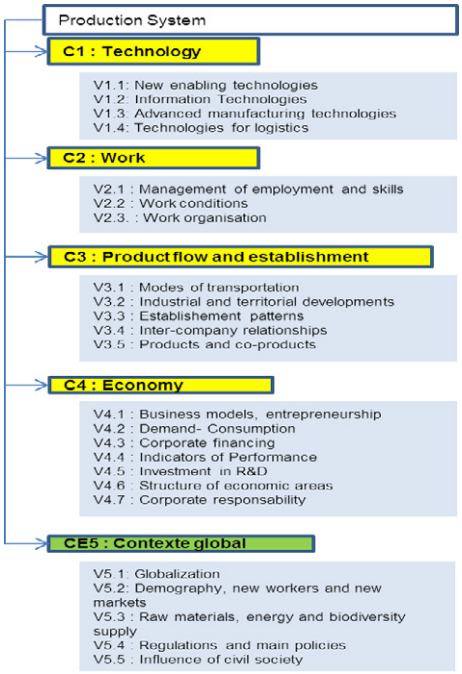

Fig. 2: Components and variables

3. Three complementary scenarios (phase 2)

A system of production is composed of three main elements in synergy to create a product: human beings, technologies and organizations. The trends and the possible breakthroughs were studied for each of these elements and so three possible images of the desirable production systems in 2030 were built. At first, systems of production were pulled by the development of the technologies with high added value was envisaged. Then the link of production systems and territories were considered to be a heavy trend of future and thus put forward the evolutions of the organization. Finally, the revival of the social contract was considered to be the main driver of the evolution of the production systems.

3.1. Scenario 1: Enabling and driving technologies with high added value

Low growth that lasts

In 2013, the situation in France is difficult and its industry is hit hard by the slowdown in global growth. Social plans are numerous and affect severely the traditional industrial sectors. Consumption of consumer technology explodes driven by prices kept low through a production in low wage countries. The permanent increase of performances leads to a continuous renewal of these products. The deficit of the trade balance in France reaches record levels. The euro-dollar exchange rates penalize exporters. Some local markets are saturated, plant location are abroad. Industrialized countries burdened by their debts gradually lose their capacity for leadership. The world is organized in different centers of power that undermine economic positions of Europe and lead to a deterioration of the social climate. Faced with economic and social situation becoming worse, the governments of European countries coordinate to provide a coherent and strong response. An economy based entirely on the knowledge will be privileged to revive sustainable growth by integrating sustainability issues (environmental, economic and social). Europe has indeed a very important intangible capital (production of knowledge and of higher and higher skills), which is an undeniable advantage against emerging countries. Many industries are driven by the expenses incurred in R & D: aerospace, pharmaceuticals, food processing and software. Proactive policies to support collaborative industry-research projects through dedicated clusters start giving satisfactory economic results.

Principles of solution: European regulation and technological innovation

Europe then bets on the potential that represent generic technologies with high added value (Key Enabling Technologies). In less than a decade, investment, public and private, for the development of knowledge bases of these technologies, R&D and production of goods incorporating them are multiplied by 10. Now, Europe is a common front and regulatory policies and regulations concerning quality, environment and working conditions are in place: industrial policies are shared and areas are specialized. Decision-making centers and industrial R&D are located in European countries and lean on research infrastructure and high level education. "Upstream" research policy is controlled by states and large organizations, "downstream" research closely associates public and private sectors.

Public investment in R&D has increased considerably and is driven at a European level. Strategic management relies on a strong knowledge of the European socio-economic practice and a detailed analysis of the needs of populations. Environmental performance is the sting of any new technology. Public policies are focused on maintaining a favorable business environment for manufacturers to maintain a competitive production while redistributing profits equitably. The creation and development of innovative companies are strongly encouraged by the government. France does not, however, abandon certain vital sectors for the country (basic consumer goods, public transport, water management and waste ...). They are assigned to social economy that supports on behalf of the public interest.

New technologies contribute to all societal and economic activities in France and Europe. The education system places strong emphasis on the teaching of science and technologies from the primary. Creativity is fostered in the teaching methods. Innovation is a priority in companies like engineering schools and universities. Higher education and research develop on one hand an important basic research in national networks to ensure first place in Europe for the production of knowledge, technology and innovation in the medium and long term and on the other hand experimental platforms in partnership with the private sector are installed in the university environment. The search results are multiplied tenfold and spread very quickly within industrial production

systems through sustainable partnerships between industries and research centers.

Indeed, companies continuously invest in R&D. Design and manufacture in France and Europe is one of their strategic focus. Specific areas of industrialization based on large-scale projects are defined by industry in partnership with states. These are primarily those where industrial power and skills exist in Europe and can integrate responses to people's needs (health, aging, sustainable development, communication, mobility, energy, personal development, leisure, personal safety security to natural hazards and technical ...). This advantage allows investing in production systems and smart products with high technology and added value and developing equipment and more effective organizations in relation to human and environmental criteria.

The development of new advanced manufacturing technologies is a priority. New manufacturing processes save energy and raw materials. It is based on cutting-edge knowledge on methods and processes of transformation, information technology increasingly powerful (computers, sensors, interfaces, virtualization tools, rapid development tools, models more close to the real models, multi-disciplinary and multi-level methods and tools for processing). The intelligence embedded in these technologies allows for very complex products with high added value and clean. The products are customized and meet people. Traditional industries have gained a clear competitive advantage through the use of these technologies that reduce production time and increase productivity, and supply the domestic market. France sees the emergence of high-tech industries that grow very competitive internationally.

For production systems (equipment, workshop, factory) these technologies provide optimization of the joint design of product, process and service. The industrial production systems become much more responsive and gain agility, flexibility and adaptability. Product and production systems performance are ensured even with high variability (achievements, specifications). New ways of cooperation and support are developed with large-scale pilot plants. Industrial organizations turn to better integrate technological advances and respond to societal goals. Production and logistics develop consistently meeting sustainability from home and office while the operational chain is distributed worldwide thanks to more efficient computer resources, software and information systems. New infrastructures and models allow the development of virtual productions of greater responsiveness and ensuring product quality and service.

Working conditions are taken into account early in the design of the production system by focusing on well-being and safety of workers, in particular by reducing the physical stress through robotics throughout the equipment life, the continuous adaptation of the workplace to the needs of staff and tasks. Cognitive dimensions of work are considered as a learning resource for the development of individuals. The nomadic work is facilitated by the development of information technology and mobility. These working conditions highlight creativity and innovation. Long life learning is facilitated and helps evolutions of qualification. Conversions are anticipated and accompanied closer to people's needs. Time and work activities are flexible and built with workers.

3.2. Scenario 2: Multi-scale circular organizations

Strong concern for the biosphere

In 2013, the demand for consumer goods and energy explodes across the globe, leading to a depletion of available raw materials and energy and water. Greenhouse gas emissions generated have a significant impact on the climate now directly threatens the lives of millions of people in areas affected by climate-related disasters. The population is growing steadily and is concentrated in huge metropoles where everyone does not eat. Problems of pollution, waste management, energy distribution, access to drinking water have become extremely problematic and states can no longer manage them. The excesses of financial globalization have accentuated inequalities around the world, including industrialized countries. The use of ICT has enabled large-scale dissemination of information extremely fast, intensified exchanges between communities through social networks and the Internet. It is a growing sense of common humanity and a growing awareness of the interdependence of human activities across the globe. States have many difficulties to provide pragmatic solutions to societal challenges which promote the rise of non-state actors. These have organized network resources and are professional. They are increasingly asked by the states in the implementation of public policy and management of humanitarian disasters. They mean a society of educated and requesting greater participation in public affairs. Global power is redistributed. Given the scale of the problems and their urgency, a global

consciousness emerges for a better consideration of human needs in their biosphere. In less than a decade, European countries and the people accept the idea of their dependence on raw materials and energy. Well-being and health have become the dominant values of society emphasizing applications of life satisfaction and compliance with eco-systems.

Principles of solution: circular economy and global indicators

Socially, expectations on companies change. They will henceforth be assessed only on their profitability. Indicators of performance also include, or even primarily, ecological and social indicators. A circular economy is a necessity and people and businesses are prepared from 2015 to the new organizational structure and society.

Globalization has evolved into a network of resilient regions. Each region meets the varied demands of local populations. Emerging countries, whose purchasing power is steadily growing, massively produce basic needs while developing a niche industry with strong technical. European countries want a new comfort adapted to the aging population which encourages industry to produce innovative and customized solutions. These regions are networked, allowing efficiency and responsiveness in the fight against global concerns such as global warming and lack of access to drinking water. Transportation is now charged at the full cost that embodies impact on the environment; world trading has been reduced to just enough. It then creates a new organization where each type of products has found a territory at the size that best suits its resource needs, market and expectations of the people.

Places of production and consumption are strongly close while providing the same performance. Life of consumer products is extended. Companies base their profitability on the minimization of the production of new and operating costs, making them less dependent on the availability of materials and energy. Maintenance, repair, recycling and reuse are the rule. Companies produce on demand as short circuits have become possible and profitable and allow increased responsiveness and customization. The concept of stock disappears in some areas.

Use quality and service are focused. Consumer demand moves from property to the satisfaction of a more personal and realistic needs. At the same time, more and more companies charge for their services to use intensity and subscriptions to services. The service economy has invested a large part of the economy. It invades first B2B for industrial goods then gradually consumer products. These new network services lean on new infrastructures, physical and organizational. Internally, companies buy new more responsive and appropriate means (micro-factory), system of management of energy, water, waste and used products to balance "energy and material" zero, organization to respond quickly to requests. Externally efficient and less consuming pooling is implemented.

Production technologies are evolving towards re-processing technologies that allow reuse of materials indefinitely by re-turning on the spot because they are already closer to users. New products are continuously created. The demand for energy is local, reasonable and on demand, which leads to a suitable reorganization of production. Industry of product re-configuration is created. New industrial processes are invented and developed: Unused and unwanted products are collected and disassembled then materials and components are extracted for new challenges. These materials are transformed into new components and reassembled in new products. Micro-factories are built near the sites of consumption. The forward and reverse supply chains are integrated. New partnerships develop within the same territory fostering circularity of materials and energy. The products are media for services that are constantly evolving. Complexity is in the set of products and services that combine in various and personalized solutions. Technologies that support this industry of re-transformation and this servicial organization play a role in the extension of this new industry and develop strongly. Information technology and communication (components, sensors, models and tools treatment) are structural. They allow greater responsiveness and "controllability". This jump requires development of suitable R&D (processes, materials, management of flows of materials and energy). New processes suited best to small series and sustainable development are implemented. Product performance is ensured even with high variability.

The use of these technologies allows organizational innovations. Jump in organization generated by these changes simultaneously induces a revolution in the organization of the education system and the labor world. The former gains flexibility in close relationships with people who stayed far away of effective learning. The latter emphasizes the quality of life, lifelong learning, mobility, protection, protection of employees, working nomad. Employment situation has improved significantly. This circular industrialization has two virtues: it consolidates jobs since they are parts of the same value chain and creates additional and local jobs in nature servicial. It calls for new businesses to interface products and services: jobs to monitor customers and jobs for the recycling and upgrading of new products.

3.3. Scenario 3: Neo-industrialization in a renovated social contract

Social cohesion close to explosion

In 2012, France and European countries have reached the limits of the social pact coming from negotiations of the post-war context since the growth is close to 0 for several years. The repeated financial crises and the rise of emerging economies have created strong tensions in companies. The rise of pension funds has led to increasing pressure on companies that must establish a short-term profitability. The rise of precarious work has created a fringe of poverty that contrasts with a relative abundance middle and upper class still protected from insecurity and brutality of certain social relations. Globalization is very rude, subject to capital movements and their volatility. Wealth is no longer shared, the future is uncertain for millions of French who do not see a solution coming for their major concerns: the care of the elderly and maintaining a decent retirement, access to decent housing, education and training for young people to access to more qualified jobs, climate change and biodiversity conservation. This very difficult social climate paves the way for a debate on the future of France and the French. Faced with an explosive situation and social, environmental, political and economic emergency, a new social pact is concluded at European level between the various stakeholders: consumers, employees and entrepreneurs. It involves the implementation of European regulations on tax harmonization and financial markets, the fight against social dumping and further standards. This new compromise allows reconsidering a common future for a developing world.

Principles of solution: social responsibility

Social relations are transformed into depth being replaced at the heart of production systems respectful of their ecological, social and economic environment. New contracts between industry and society develop on the basis of a wider social and environmental responsibility and accepted. This is a long-term logic taking over a logical short-term.

Under the leadership of the European Union a new organization of markets is setting up. New regulations in the financial world are implemented. Unfair competitive practices are tracked and convicted. The speculative capital movements are heavily taxed. New international regulations that are more stringent.

In a sanitized and secure financial context European Union has a committed and proactive policy with all stakeholders and coordinates the efforts of countries in the following areas: harmonization of social legislation focusing on the most protective legislation, the support for companies that innovate in developing industrial processes and eco-design processes, new products-services oriented business, harmonization of education systems. Education and training in particular areas are back to the top priority. Professional organizations anticipate the change in skill needs. Long life learning is at the heart of industrial enterprises in particular to ensure the transmission of knowledge between generations.

The company has become a place that promotes skills development and social cohesion. Geographical and occupational mobility are consistent, the working path is secure throughout life, the development of technology enables mobile working and everyone can build and organize its own connection between work and private life. Young Europeans spread progressive values of social, environmental and political relationships that transform social relationships. Prized by companies for its creative capacity, this population is demanding to companies that employ them. It seeks to reconcile private and professional life. Career is not the only objective of executives. Preserving the quality of life is also a criterion in the choice of the company and the position.

Efforts are made to install a dynamic process of technological, organizational and social innovation. This dynamic is particularly spurred by strong awareness of people and company to the issues of well-being at work, environmental issues and ethics. People buy more services whose products were eco-designed, environmentally and socially responsible. Products are smart, customized, multi-technology and support many services. To meet this demand, companies focus innovation by integrating the earlier the user in the design process. It contributes to the design but also the production through open innovation platforms available on the network. The intellectual and industrial property disappears in favor of flexible arrangements between partners where the exchange and sharing of data is the rule. The user also contributes to renew functionality through use practices and so to develop new services. More informed and attentive to his mode of consumption, it is a full partner in the business and do a consume anonymously.

The development of these forms of open, transverse, continuous innovation relies heavily on knowledge. Access, storage, integration, dissemination and use of knowledge are an essential element of organizations. The ability of firms to manage external knowledge and to value it is a discriminant asset. Only companies able to put in place mechanisms to integrate external knowledge (learning organizations) and spread them (e-learning) could develop. It is not new IT developments

in the context of ICT-based economy but new technologies of information and communication within an ICT-based society. Associated with recent development of the internet, social networks and virtual reality have profoundly changed the way of life in the areas of politics, education, entertainment, etc. The impact on the structure of education and training is important; everyone has access to a multitude of cognitive content and builds their learning.

Innovation capacity required to meet the demands of consumers require new production systems controlled in project mode. Companies work in partnership, resources and personnel pooling for a limited period either at the design stage, production or distribution of the product. This involves the development of extensive business, flexible and responsive networks. The creation of knowledge bases is an essential element of this network organization. Knowledge must be transverse, distributed and networked accessible quickly, hybrid, integrated, applied and personalized, consolidated with the establishment of standards and models, better exploited and transformed into technological device for learning, more collaborative and shared between different categories of users more or less experts. This leads to a balanced development of technologies between the high-tech technologies and those related to the re-processing and recycling, with the constant concern of saving material and energy.

New forms of work have emerged in which information technology and communication are central. Workers are multi-skilled and highly skilled. Cooperation has become the main mode of organization of private and public actors. Organizations favor a pilot project mode with combination of ad-hoc skills to meet the needs of society in terms of health, housing, education and energy management. Public-private partnerships are privileged to meet major societal problems (epidemics, vaccines, food issues). International research institutions clusters are created to perform scientific programs requiring very large pooling of resources and means.

4. Discussion and conclusion: what is really moving for the production systems of the future?

All the experts finally converged on three great shifts that are strongly going to impact the production systems and can structure the reflection on research.

- The industry becomes a central and open actor of the society in which it lives and an industrial performance is to be rethought. The industry goes out of its relative autarky to take back a justifiable place at the center of the society. The challenge is to develop production systems with the properties expected by society: a request of wealth, security, employment, pleasant work, environmental protection. The global scientific objective is to design these new systems and be capable of piloting them to obtain the right performance.
- New actors who are not technicians of the production go into the circle of the actors of the production systems and it is a question of inventing the way of interacting between all these people. They need their indispensable place. They have to be not only influencing but also co-designing the systems with the industrial actors. The challenge is to develop production systems allowing these actors of varied natures and cultures to interact with this industrial world through new qualities of more responsibility, collaboration, partnership, opening, innovation, transparency. The global scientific objective is to design the mechanisms which are going to allow transforming these relations.
- An industrial revolution is growing with the generic and enabling technologies and it is quickly necessary to be interested in the usages and to build them. The challenge is to take into account these new capacities to rethink new production systems. This knocks down the existing technologies and organizations but also announces very new designs from technologies to be invented. The uses of these technologies are to be built in their whole dimensions of the production systems. The global scientific objective is to design which gives industrial advantages and achieve the need for social progress. The development of these technologies keeps pace with the development of the associated skills.

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