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MODEL OF INNOVATIVE SMART ENTERPRISE

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Abstract: *The introduction of the Internet of Things and Services into the manufacturing environment is ushering in a fourth industrial revolution: Industry 4.0. This new type of industry is based on Smart Factory model or Smart Enterprise. The main features of Smart Enterprise can be summarized into the following: smart personalized product, product and service provider and high level of collaboration. This paper presents the state of the art overview on today's manufacturing technology and organization trends. Also, the main objectives of project "Innovative Smart Enterprise (INSENT)", that is specialized product configurator which will be developed for Mass Customization principle is shown.*
Keywords: ***Smart Enterprise, Manufacturing Systems, Smart Product***

1. INTRODUCTION

Number of customers and their demands frequently changes, forcing producers to cope with larger variability in production. Despite higher production costs, interest in the MC products is often higher than for comparable cheaper standardized products.

Manufacturing is today, as it always has been, a cornerstone of the economy of developed nations. Having a strong base of manufacturing is important to any advanced country because it impels and stimulates all the other sectors of the economy. It provides a wide variety of jobs, both blue- and white-collar jobs, which bring higher standards of living to many sectors in society, and builds a strong middle class. An important advantage of manufacturing is that it creates a whole range of diverse jobs. Whereas agriculture and construction generate lots of low-skilled jobs, and art and software create a few jobs for higher-skilled elites, manufacturing calls on the skills of everyone from entry-level factory workers to scientists, engineers, and business professionals.

Vision of Innovative Smart Enterprise for next generation manufacturing can be summarized into following features: Lean, Flexible, Agile, Efficient, Responsive, Information Enabled, Predictive, and Safe. All these features result with long term sustainability of Innovative Smart Enterprise.

2. STATE OF THE ART

The process of globalization, liberalization of international trade and the global economic crisis in 2007 showed that the classical vision of the enterprise and its business activities cannot survive in today's turbulent economy. It is the reality, not only for production-oriented enterprises, but for service-oriented enterprises too. Because, today's enterprise needs to have a high degree of specialization in its field, and, at the same time, a flexible and fast response (new product or service) to the needs of customers (a very specific ones and a wide range ones). That creates a new vision of a modern enterprise which needs to unite contradictory requirements: specialization and flexibility.

According to Koren [1] globalization has created new enormous challenges for today's enterprises: fierce competition, short windows of market opportunity, frequent product introductions, and rapid changes in product demand. Globalization is also driving dramatic changes in the production systems of large enterprises. Many manufacturing enterprises have moved away from a mass production orientation to more agile production approaches [2]. Although globalization is challenging, it also presents opportunities, not only threats. The challenge is to succeed in a turbulent business environment where all competitors have similar opportunities, and where customer wants personalized product. First type of personalized product is [1]: Product's regional fit. It means that, besides culture and market, regionalization must take into account additional limitations: purchasing power, climate, and legal regulations (safety, environmental limitations, etc.). And second type of personalized product is [1]: Product personalization. It refers to products that are manufactured to fit the buyer's exact needs are likely to become a new source of revenue in developed countries. Product's regional fit requires manufacturer's flexibility, and Product personalization requires manufacturer's flexibility and specialization. Traditional Flexible Manufacturing Systems are not able to fulfil those requirements and to be economical in the same time. There is a need of new manufacturing systems, like the one presented by Koren in 1999 [3]: Reconfigurable Manufacturing System (Fig. 1).

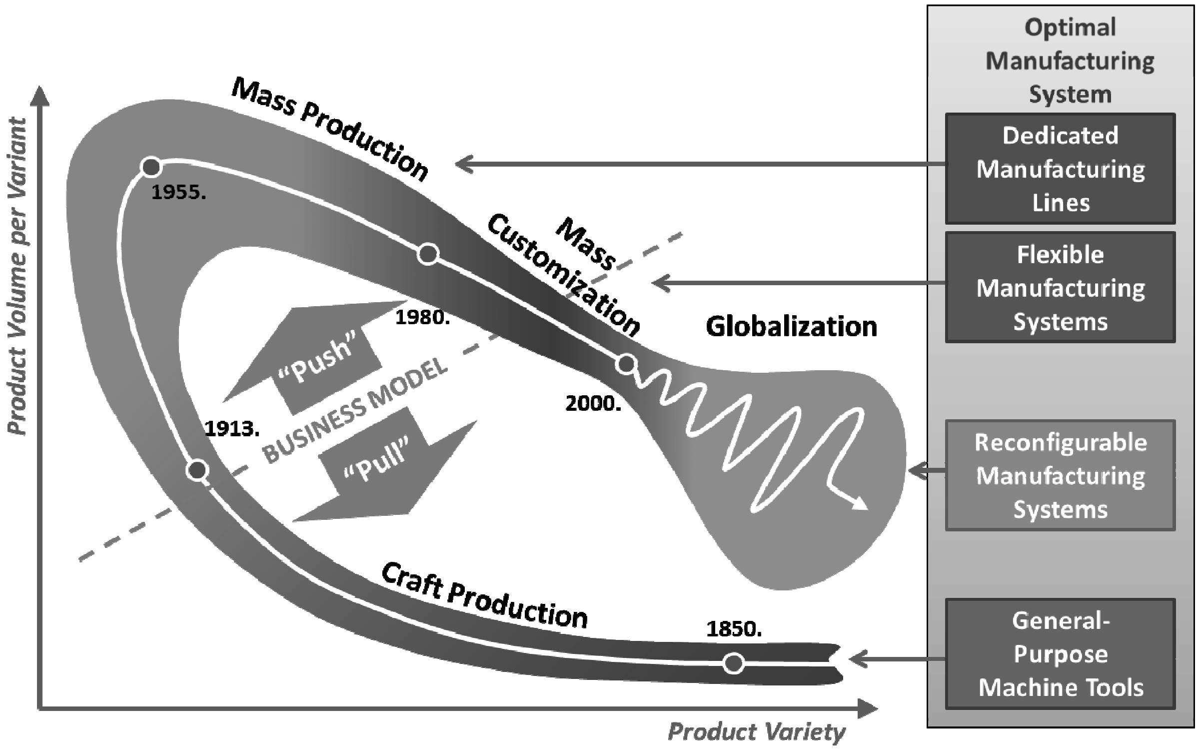

Fig. 1. The product architecture and the optimal manufacturing system [1]

The Reconfigurable Manufacturing System has three main principles [1]: it provides adjustable production resources to respond to unpredictable market changes and intrinsic system events, it is designed around a product family, with just enough customized flexibility to produce all members of that family, and its system core characteristics should be embedded in the system as a whole, as well as in its components (mechanical, communications and control). Such a system possesses flexibility of Flexible Manufacturing Systems and productivity of Dedicated Manufacturing Lines [4]. Implementing characteristics and principles of Reconfigurable Manufacturing System leads to achieving the ultimate goal: Living Factory [4] or Smart Factory [5]. Such a factory can rapidly respond to needs of customer adjusting its production capacity and product design while maintaining high levels of quality [1].

Furthermore, the first three industrial revolutions came about as a result of mechanization, electricity and IT. Now, the introduction of the Internet of Things and Services into the manufacturing environment is ushering in a fourth industrial revolution: Industry 4.0 [5]. This new type of industry is based on Smart Factory model (Fig. 2). The Smart Factory has a completely new approach to production: smart products are uniquely identifiable, may be located at all times and know their own history, current status and alternative routes to achieving their target state. The embedded manufacturing systems are vertically networked with business processes within enterprises and horizontally connected to the dispersed value networks that can be managed in real time [5]. Smart Factories allow individual customer requirements to be met and mean that even one-off items can be manufactured profitably. In Industry 4.0, dynamic business and engineering processes enable last-minute changes to production and deliver the ability to respond flexibly to disruptions and failures on behalf of suppliers, for example. End-to-end transparency is provided over the manufacturing process, facilitating optimized decision-making [5]. Industry 4.0 requires implementation of following features into enterprise [5]: horizontal integration through value networks, end-to-end digital integration of engineering across the entire value chain, and vertical integration together with networked manufacturing systems. To implement these features, an enterprise must be Smart Enterprise, i.e. it must incorporate its machinery, warehousing systems and production facilities in the shape of Cyber-Physical System [5] (smart machines, storage systems and production facilities capable of autonomously exchanging information, etc). The industry is becoming aware of this idea of Industry 4.0. Modern information and communication technologies like Cyber-Physical Systems, Big Data or Cloud Computing predict the possibility to increase productivity, quality and flexibility within the manufacturing industry and thus to generate advantages within the competition [6].

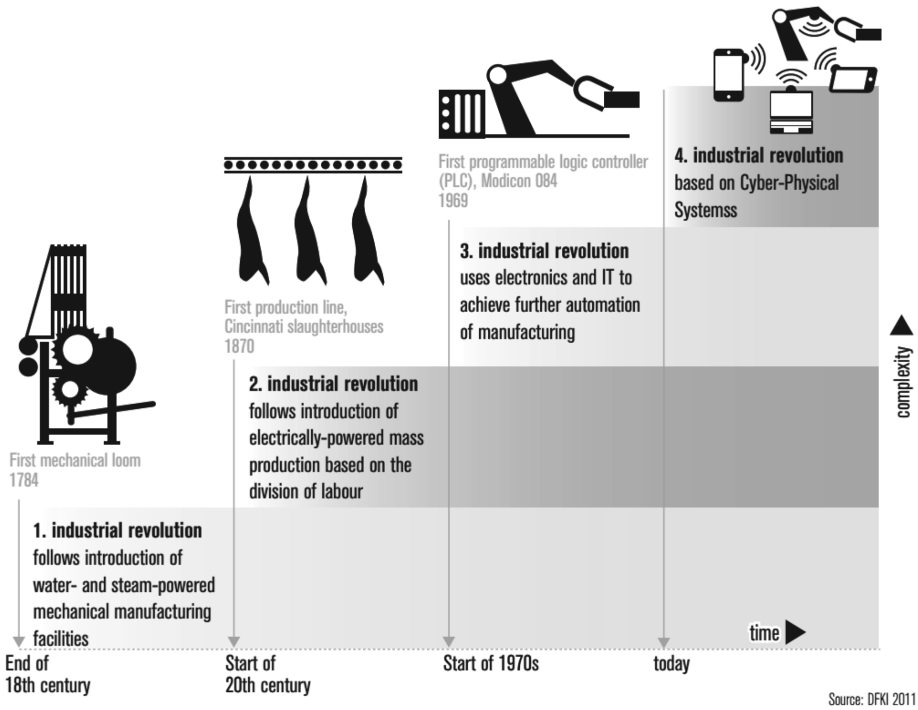

Fig. 2. The four stages of the Industrial Revolution [5]

The Cyber-Physical System of Smart Factory is crucial to support new business models for manufacturers called: Manufacturing-as-a-Service [7], Industrial Product-Service Systems [8] [9], or similar. Idea of Industrial Product-Service Systems is extended product [8], i.e. product and service integrated into single product for delivering value in use to the customer during the whole life cycle of a product [10]. However, the idea of Manufacturing-as-a-Service is to transform manufacturer of product or part to manufacturing service provider. Both business models incorporate services into manufacturing enterprises [9], and both require usage of state-of-the-art ICT. Because of that these models can only function around an Internet portal [11]. The aim is to automatically generate process plans and quotations are from the technical product data provided over Internet portal [12]. After customer assent, the prices, transportation costs and delivery times determine the choice of the standardized production plant. Hence, the importance of ICT integration into enterprise's processes and organization is crucial [13]. That is the reason why such a Cyber-Physical Systems are called Smart Factory or Smart Enterprise.

As mentioned, one of the main requirements of today's enterprise is to be collaborative [14] [15]. Collaboration of enterprises enables new virtual organizational structure called Virtual Enterprise [16]. According to Camarinha-Matos [17] Virtual Enterprise is a temporary alliance of enterprises that come together to share skills or core competencies and resources in order to better respond to business opportunities, and whose cooperation is supported by computer networks [18]. Virtual Enterprises materialize through the integration of skills and assets from different enterprises into a single business entity without forming a new legal entity nor establishing a physical headquarter. Virtual Enterprises are usually realized through Production Networks or Manufacturing Networks. Production Networks represent the whole value adding process (marketing, product development, production planning, manufacturing, assembly, quality control and service), so they represent vertical integration of enterprises [5] [20]. And Manufacturing Networks represent only manufacturing and assembly process, so they represent horizontal integration of enterprises [5] [19]. In many countries, Production Networks has been recognized as new model of industrial organization [20] [21] [22]. However, there are three significantly developed models of Production Networks: Competence-cell-based network, Complexity-based model, and Core Competence Cell model. In Competence-cell-based network [23] [24] each enterprise represents a single competence-cell, since the employees of each company have a specific set of competencies [25]. However, each competence-cell retains its autonomy, because this network is non-hierarchical. A competence cell is considered as smallest autonomous indivisible performance unit of value adding. The human competences of each cell are obtaining crucial importance, so the human is in the center of the competence cell [25]. In Complexity-based model [26] the dynamic behavior of a Production Network is modelled as a Complex Adaptive System (CAS). A CAS can be considered a multi-agent system with seven basic elements in which a major part of the environment of any given adaptive agent consists of other adaptive agents, so that a portion of any agent's efforts at adaptation is spent adapting to other adaptive agents. Agents may represent any entity with self-orientation, such as cells, species, individuals, enterprises or nations. In Core Competence Cell model [27] is reducing structural complexity of growing organizational systems like Production Networks by reducing cells (enterprises) to core competence cells, i.e. to three basic types: dealer, producer and service provider.

Finally, the main features of Smart Enterprise can be summarized into the following:

- Smart personalized product – Requires flexibility and high level of ICT integration into manufacturing system to produce a product which fits the customer's exact needs and which is uniquely identifiable, may be located at all times and knows its own history, current status and alternative routes to achieving customer. It can be realized through Reconfigurable Manufacturing System [1] or Industry 4.0 Smart Factory [5].
- Product and service provider – Ability to offer extended products: product and service integrated into single product for delivering value in use to the customer during the whole life cycle of a product [8]; or to offer manufacturing as a service and become manufacturing service provider [7]. It can be realized through specialized Internet portals and Cloud computing [7].
- High level of collaboration – Also requires high level of ICT integration to support collaborative product development, collaborative manufacturing and all other value adding processes [28] [29]. It can be realized through vertical integration called Production Networks [20], or through horizontal integration called Manufacturing Networks [19].

3. OBJECTIVES OF DEVELOPMENT OF INNOVATIVE SMART ENTERPRISE

Last year's developments are a turning point for the whole European industry, characterized by a dramatic drop in customer demand leading to reduced working hours, layoffs and idle factories. As a consequence, in the future the overriding objectives in Croatian enterprise will be flexibility, agility and scalability, in order to survive turbulences caused by erratic customer behavior on one hand or market turbulences on a large scale on the other hand.

The main objective of project INSENT is to develop "Model of Innovative Smart Enterprise (ISE model)". The aim is to perform model's regional fit, i.e. to harmonize Innovative Smart Enterprise model with specific regional way of thinking, manufacturing and organizational tradition, specific education, and especially to help Croatian enterprises to bridge the gap between their competencies and EU enterprises' competencies and capabilities. Following objectives are crucial to achieve main objective of project INSENT:

- Objective 1: It is important to perform profound research to describe current state of Croatian manufacturing enterprise. It will be done by questionnaires and interviews with CEOs and/or technical directors of manufacturing enterprises. The aim is to gather the data from as much as possible enterprises. After that, analysis will be done to describe current state of manufacturing enterprise. It will be the answer on the question: "Where are we?"
- Objective 2: A synthesis of analysis of manufacturing enterprises will be done through development of "Model of Innovative Smart Enterprise (ISE model)". ISE model will be based not just on State-of-the-art theoretical models but also on State-of-the-art practical models like Lean Management philosophy from Toyota Production System. A special effort will be made to bridge the cultural and mentality gaps between State-of-the-art models and current Croatian model. It will be the answer on the question: "Where we want to be?"
- Objective 3: A special learning environment will be established in one Laboratory. It will be a Learning Factory, i.e. simulation of a real factory through specialized equipment (virtual reality gadgets, specialized assembly stations, real and didactic products, automatic assembly station, etc). Laboratory will be organized to simulate factory based on ISE model. Hence, Laboratory will be learning environment not just for students but for engineers from manufacturing enterprises. It will be a place in which transfer of developed ISE model to the economy subjects will be achieved. All supporting material and equipment for education will be provided. It will be the answer on the question: "How can we get there?"

4. PRODUCT CONFIGURATOR

Product configurator development is one of the working packages in mentioned project.

So far it has not been proven that any kind of production can make the entire production process more efficient than the mass production. Therefore, it can be concluded that with the increasing demands of a product variants manufacturing process of the enterprise should use Mass Customization (MC) principles. With the flexibility of production, the vast majority of Croatian manufacturing systems have not reached a degree of flexibility demanded by MC systems, including Lean manufacturing.

One of the keys to the success of MC is to make quality design tool (configurator).

Enterprises want, with increasing market demands, to achieve a number of re-use, but not in terms of re-use of the product after it has achieved its primary application, but re-use of components, documentation, production processes etc. Enterprises are faced with the challenge of ensuring greater variability of the product on the market, but with a small difference (in construction, manufacturing, maintenance) among the variants. Therefore, the development of product variants should be considered as a configuration of new products from previously defined modules, or based on same product platforms. On the other side, customers do not want the limited choice, that is only offered options, but want their own individual product. The configurator must help them to understand exactly what they want. With offered configuration a customer has to be educated about the specific product in a way that is familiar with the components of the product, which encourages innovation. All manufacturers have already defined some of the offerings, but each customer should be able to choose some of the characteristics of products or add some.

Configurator will have three main components:

- The core configuration software which presents possible variations and leads the user through the configuration process by asking questions or leaving the formatting options.
- Tool for feedback which is responsible for representing the configuration. Feedback to design variants can be visualized as a dedicated or in other forms (e.g., price information, the test functions, time to deliver) and provides a basis for user learning.
- Advanced analysis tool translates the customer's final selection to a specific list of materials, construction plans and work plans. Furthermore, the configuration of production can be made or sent to other departments.

After delivery of customized products, the manufacturer should use feedback from the customer for the next period, which ensures faster and easier production. The database will increase and will be updated with each additional purchase. Costumer needs are not constant but they are constantly changing, so the company must take into account the recognition of future consumer needs and to plan future products and services.

One of most important thing concerned with customer satisfaction with company's offer is time necessary for delivery of ordered configuration. Time estimations which are randomly set by producer are often incorrect, and they are playing a big role in company reputation. On one side, longer period to supply then necessary can make potential customer to choose another company, and on the other side, longer period for delivery then estimated, can make a customer very dissatisfied and disappointed. In internet era, market globalization and extensive information sharing, not only among professional networks, but also on social networks, dissatisfied customers can make big impact on company survival.

Many companies that have achieved great success with software for the MC, were met with great challenges and costs in making the interaction model. Although many companies recognize the huge profits from the software, yet the cost and risk are the barriers to adoption of new software tools. Sales and marketing are focused on the added value of customized products, while engineers are reluctant because of the high risk, large investments and costs. Developed configurator should be able to immediately estimate total costs of raw material parts and semi products which are supplied from upstream companies in supply chain. For estimation of production costs, production processes data, about staff cost, machine work, tools, amortizations and all fixed costs should be applied. It will be very demanding to implement such a concept due to requisite that design, construction and production technology department should prepare all documentation regarding to requested configuration. To some extent, it could be resolved with experience data in recent production period, which will also be included in configurator.

However, long-term system for the realization of interaction with customers is one of the key factors for cost reduction. Configurator will be defined as a software tool for the implementation of MC strategies, which allows the manufacturer to automatically generate a product-based information requirements set by the user. Development of a high quality system configuration is very important for every enterprise regardless of the level of implementation of the MC.

5. CONCLUSION

It is expected that results of project INSENT will be of high value for Croatian industry which is affected by recent crisis. The development of "Model of Innovative Smart Enterprise (ISE model)" and its transfer to economy, using "How can we get there?" approach i.e. establishment of special learning environment through Learning Factory, could have strong impact on recovery of Croatian industry. Especially, it could help improve competencies and capabilities of Croatian enterprises to make them more competitive on EU market. According to usual Lean implementation benefits [30], it can be expected that implementation of ISE model could help enterprises to reduce operating costs up to 15%, to shortage time to delivery for about 30%, with a 10-20% increase of capacity utilization. Furthermore, results of project INSENT could be valuable for all countries with mentality and culture similar to Croatian, namely Hungary, Poland, Czech Republic, Slovakia, Bosnia and Herzegovina, Serbia, Montenegro, Bulgaria, etc.

6. ACKNOWLEDGEMENT

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