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IFAC-PapersOnLine 48-3 (2015) 555–560

Managing Innovative Production Network of Smart Factories

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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 model of Smart Enterprise, i.e. Smart Factory. The main features of Smart Factory are production of smart personalized product, products and services are integrated, and high level of collaboration is achieved through Production Networks. Furthermore, Innovative Production Networks are seen as one of key elements of Industry 4.0. This paper presents management of Innovative Production Networks using MCDM method to achieve automated optimal partner selection for new value chain.

Keywords: Industry 4.0, Smart Enterprise, Production Networks, Innovation, Multi-Criteria Decision Making.

1. INTRODUCTION

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. Today's manufacturing enterprise must produce complex products that require high degree of specialization, and, at the same time, products must be personalized requiring flexible and agile response to meet the needs of modern customers (a very specific requirements and a wide range of needs). It creates a new vision of a modern manufacturing enterprise. Enterprise that must unite contradictory requirements: specialization and flexibility (Fig. 1).

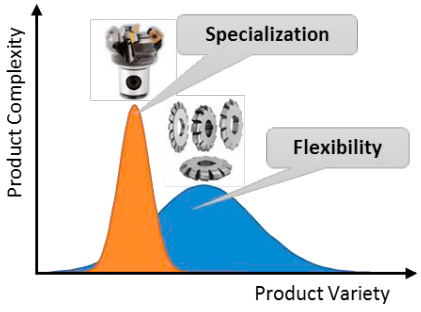

Fig. 1. Specialization approach and flexibility approach to definition of product(s) complexity and variety

Therefore, many manufacturing enterprises have moved away from a mass production orientation to more agile production approaches (Pasek et al., 2004) (Fig. 2). According to Koren (2010) the challenge for manufacturing enterprise is to succeed in a turbulent business environment where all competitors have similar opportunities, and where customer wants personalized product. 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 (2010): Reconfigurable Manufacturing System.

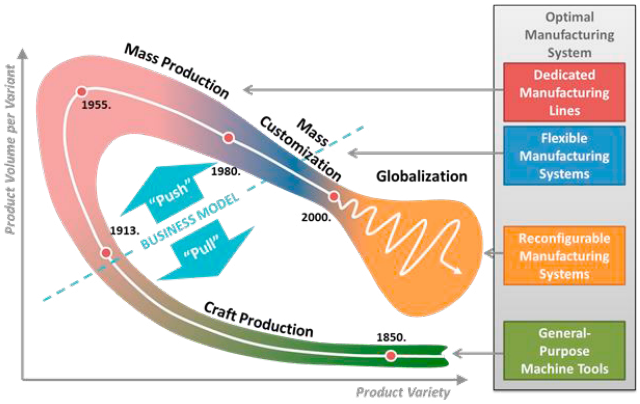

Fig. 2. The product architecture and the optimal manufacturing system (Koren, 2010)

The Reconfigurable Manufacturing System has three main principles (Koren, 2010): 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 (Koren, 2010). Implementing characteristics and principles of Reconfigurable

10.1016/j.ifacol.2015.06.139

Manufacturing System leads to achieving the ultimate goal: Living Factory (Koren, 2010) or Smart Factory (Kagermann et al., 2013). Such a factory can rapidly respond to needs of customer adjusting its production capacity and product design while maintaining high levels of quality (Koren, 2010). Furthermore, Smart Factory represents key infrastructure element of new industrial platforms like Industry 4.0 (Kagermann et al., 2013).

2. SMART FACTORY

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 (Kagermann et al., 2013). This new type of industry is based on Smart Factory model. 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 (Kagermann et al. 2013). 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 (Kagermann et al. 2013).

Industry 4.0 requires implementation of following features into enterprise: 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, i.e. Smart Enterprise / Smart Factory. It must incorporate its machinery, warehousing systems and production facilities in the shape of Cyber-Physical System (smart machines, storage systems and production facilities capable of autonomously exchanging information, etc). The Cyber-Physical System of Smart Factory is crucial to support new business models for manufacturers called: Manufacturing-as-a-Service (Meier et al. 2010b), Industrial Product-Service Systems (Meier et al. 2010a), or similar. Idea of Industrial Product-Service Systems is extended product (Meier et al., 2010b), 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 (Saaksvuori and Immonen, 2005). 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 (Váncza et al., 2011), and both require usage of state-of-the-art ICT to be able to function through an Internet portal (Ten Dam et al., 2009). The aim is to automatically generate process plans and quotations are from the technical product data provided over Internet portal. After customer's 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 (Boucher and Yalcin, 2006). That is the reason why such a Cyber-Physical System is called Smart Factory. So, the main features of Smart Factory can be summarized into the following:

- *Production of 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. It can be realized through Reconfigurable Manufacturing System (Koren, 2010) or Industry 4.0 Smart Factory (Kagermann et al., 2013)
- *Product and service are integrated into single extended product* – Ability to product and service integrated into single product for delivering value in use to the customer during the whole life cycle of a product (Meier et al., 2010a); or to offer Manufacturing-as-a-Service and become manufacturing service provider (Meier et al., 2010b). It can be realized through specialized Internet portals and Cloud computing (Meier et al., 2010b).
- *High level of collaboration through production networks* – Also requires high level of ICT integration to support collaborative product development, collaborative manufacturing and all other value adding processes (Mourtzis, 2010; Neuberta et al., 2004). It can be realized through vertical integration called Production Networks (Sturgeon, 2002), or through horizontal integration called Manufacturing Networks (Markaki et al., 2013).

In this paper research aspect is on achieving high level of collaboration through production networks using automated partner selection process.

3. INNOVATIVE PRODUCTION NETWORK OF SMART FACTORIES

An Innovative Production Network 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 network (Camarinha-Matos and Afsarmanesh, 2007). Two key elements in this definition are the networking and cooperation. A number of pre-existing enterprises or organizations with some common goals come together, forming an interoperable network that acts as a single organization without forming a new legal entity nor establishing a physical headquarter. In other words, they form a Virtual Enterprise (Camarinha-Matos and Afsarmanesh, 2007).

Production Networks are seen as one of three key elements of Industry 4.0 (Fig. 3.). Since Industry 4.0 is based on factories that are Smart Factories, these factories already have preposition to achieve information exchange in real-time across enterprises borders. It allows creation of flexible value chain that can have innovative product development and agile