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Intelligent production planning and control in the cloud – towards a scalable software architecture

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Abstract

Today's manufacturing companies are undergoing a transformation towards increased digitalization, automation of manufacturing processes and as well new forms of manufacturing organization and business models. While large-size manufacturing companies are able to follow the pace of such technological developments, small- to mid-size manufacturing companies (SME) often experience substantial problems in adopting technologically and organizationally far reaching concepts as for example propagated by Industry 4.0. In this paper we will discuss a particular problem area of SME – production planning and control – in the light of future manufacturing scenarios. We will outline typical requirements regarding production planning and control in small- to mid-size companies and will propose a scalable cloud-based architectural concept for an intelligent production planning and control (iPPC) software service that we are currently developing as a research prototype and demonstrator solution for industry.

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Keywords:

1. Introduction

Today's manufacturing companies are undergoing a transformation towards increased digitalization, automation of manufacturing processes and as well new forms of manufacturing organization and business models. These developments are driven by recent technological developments and visionary concepts such as the Industrial Internet, Internet of Things, Big Data, Smart Manufacturing and politico-economically motivated programs such as The Fourth Industrial Revolution (aka Industry 4.0).

While large-size manufacturing companies are able to follow the pace of such technological developments, small- to mid-size manufacturing companies (SMEs) often experience substantial problems in adopting technologically and organizationally far reaching concepts as for example propagated by Industry 4.0.

Small and medium-sized enterprises (SMEs) account for over 95% of firms and 60%-70% of employment. They create a large share of new jobs in OECD economies. New technologies and globalization decrease the importance of economies of scale in many activities. Therefore, smaller firms potentially will have the chance to increase their overall contribution in the value chain. However, SMEs have specific strengths and weaknesses. Typical problems faced by SMEs are lack of financing, difficulties in exploiting technology, constrained managerial capabilities, low productivity, regulatory burdens. These problems become even more acute in a globalized, technology-driven environment. [1]

One promising approach that is also being addressed on a political level is the fostering of small-firm networks and clusters. As part of dynamically forming networks of production SMEs can potentially be more flexible and responsive to customer needs than large firms. Such networks can pool resources and share the costs of training, research and development, maintenance and as well planning and control [2].

Cloud-based manufacturing is a new paradigm that builds upon the concepts of service-orientation and virtualization of software resources and underlying hardware [3]. It is not only

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a technological concept that offers ubiquitous accessibility of data and applications but is also an economic opportunity for small- to mid-size manufacturing companies to participate in and benefit from recent technological advancements. Cloud-based manufacturing is expected to enable flexible production network formation to meet an increasing variance in customer demands within reasonable delivery time and low capital tie up [4].

In this paper we will discuss a particular problem area of small to mid-size manufacturing companies – production planning and control – in the light of smart and network manufacturing of the future. We will outline typical requirements regarding production planning and control in small- to mid-size companies and will propose a scalable cloud-based architectural concept for an intelligent production planning and control (iPPC) software service that we are currently developing as a research prototype and demonstrator solution for industry.

2. Challenges and requirements for SMEs

2.1. Challenges

According to the classification scheme of the European Union (EU) Small- and Medium-sized Enterprises (SMEs) employ not more than 250 people and do not have a turnover of more than 50 million Euro. In fact, 99.8 % of European firms (non-financial) fall into this class. However, a closer look into recent statistics reveal that 92.7% of firms are actually micro firms with not more than 10 persons employed. SMEs account for 67% of EU's employment and 58% of value added [5].

In the manufacturing sector 20 % of all enterprises are SMEs. They account for 59% of the employment in this sector and 44 % of the value added. About 80% of the value added is contributed by small and medium sized companies with more than 20 and less than 250 employees. The sectors where small and medium enterprises create almost half of the value added are machinery and equipment, fabricated metal products and food. Other important sectors for SMEs are rubber and plastics, chemicals and electrical equipment [5].

SMEs have a large share in overall economic performance of the EU and as well all other world regions. However, SMEs are also the first-in-row to experience economic turbulences. In fact, SMEs disproportionately negatively contributed to employment decline during years 2008 to 2013 but also contributed disproportionately to the subsequent recovery in 2014. Among the most pressing problems that SMEs experience in recent years are an increasing competition, lack of financial resources, shortage of qualified staff and regulation. Production costs are a problem that SMEs face ever since due to a relatively (in comparison to large firms) high share of human labor in manufacturing processes [5, p. 12].

The latter problem of high labor intensity refers to the larger problem area of efficiency management in SME production processes – a problem area that has been recently investigated for example by Matt and Rauch [6]. Accordingly, SMEs are either not aware of the benefits of lean management or do not have the knowledge to implement respective management concepts. In addition to the knowledge gap lack of financial resources is found to restrain SMEs from investments in advanced production planning and control systems which potentially can increase overall efficiency [7].

A problem area attracting increasing attention from EU policy makers is the fact that SMEs are somehow reluctant to cooperation and networking. Several studies (see e.g. [1], [2], [8], [9]) have shown that SMEs with a strong network of business partners and more specifically innovation partners are more likely to succeed in the long term than those that do not. A main obstacle for cooperation and networking are again the limited resources SMEs own, to initiate and sustain a cooperative venture [2, p. 16]. Despite the reluctance to initiate and maintain cooperation SMEs are usually strongly embedded in a supply chain network which is especially true for the machinery and equipment manufacturing sector. The competency, responsibility and costs of managing such a network is then left over to the hands of large firms, e.g. in the automotive sector, with the price of a strong dependency on the focal firm.

For a subsequent outline of meta-requirements for production planning and control we want to stay with this twofold view – individual and network view – on SMEs.

2.2. Meta-requirements

For an analysis of meta-requirements, we use a typical PPC process as a reference framework. Typical activities in PPC can be divided into long- range and short- range planning activities and ongoing control activities.

2.2.1. Long-range Planning

Long-range planning goes in hand with the overall business planning activities of a manufacturing company. A company's business vision and derived long-term objectives are the reference point for long-range planning. The outcomes of long-range planning are rough-cut production programs that indicate the product families, the quantities to be manufactured and the human and technical resources needed.

In practice SMEs rarely have explicit strategies regarding their business future [10]. Rather SMEs aim at staying highly responsive to market needs. Therefore, Make-To-Order (MTO) and Engineer-To-Order (ETO) principles are increasingly applied among SMEs [11]. However, also for MTO and ETO manufacturing resources have to be planned in advance.

Long-range planning therefore requires a solid base of a company's historical sales data and its linking with future-oriented data such as market developments and technological trends. Data sources need to be exploited (e.g. social media data) to anticipate the future development of product offerings and the required machinery. For SMEs within a supply chain network these data can potentially be collected from the focal firm or other downstream partners in the supply chain.

Long-range planning for production networks requires a central planning unit that collects and maintains data from the involved network partners to be able to learn for future decisions regarding optimal network configurations [12].