# Towards a cloud-based manufacturing execution system

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***Towards a cloud-based manufacturing execution system:*** *This paper illustrates the needs and challenges for the management of distributed manufacturing in a multi-company supply chain and processes considering new IT systems. Requirements are collected from literature in the field of current ERP/MES system drawbacks, advantages, needs and challenges. Current ERP-solutions lack extended enterprise support and a shared cloud-based approach with architecture for next generation of MES solution is proposed.*

***Key words:*** *Cloud, Distributed manufacturing, Supply Chain and Processes.*

## INTRODUCTION

Today's business supply chains for complex products are likely to involve a number of autonomous organizations. The competitive market requires that these supply chains are highly agile, effective and efficient. Agility and effectiveness are obtained by forming highly dynamic virtual enterprises (VE) within supplier networks [7]. All these highlight the importance of information technology in integrating suppliers and other partners' firms in a virtual enterprise and supply chain [6]. Interoperable enterprise systems are the key to enterprise integration [39]. Supply chain management (SCM) is a way of obtaining horizontal integration benefits without its formal ownership costs. SCM, the integration of key business processes among industry partners, adds value to customers, tightly links together several consecutive elements of the industry value chain, from upstream suppliers, to subassembly manufacturers, to final manufacturers, to distributors, to retailers, to end-customers, in order to make the processes more efficient and the products more differentiated [1]. The internet has brought forth numerous possibilities to increase this flow of information, and encouraged companies to form closer integration of their information services (IS). The adoption of the internet and turbulent market conditions have forced small and medium-sized enterprises (SMEs) to adapt their way of undertaking business, from traditional practice to e-business [2]. Current ERP technology provides an information-rich environment that is ripe for very intelligent planning and execution logic. Yet little has changed since the late 1970s in terms of logic associated with such applications as forecasting, reorder point logic, MRP, production scheduling, etc. The current systems are now just executing the old logic much faster and in real-time. The area is ripe for innovative new approaches to these old problems [10]. Particularly in the manufacturing industry, current ERP-solutions appear short in terms of supporting multiple plants, multiple suppliers, and lack functions such as inventory control, management planning and production order processing. Therefore, to manage the factories, manufacturing execution systems (MES) are designed to perform functions such as production control, maximize the workload of equipment, release unneeded machine tools, etc. Nowadays, the problem is how to integrate all these applications and solutions in a single platform in order to bundle all virtual enterprises into one supply chain and manage them centrally. The paper goes in two major contributions. First, the limits of current software solutions as applied in distributed manufacturing are discussed and a solution integrates both the concept of ERP and MES are outlined.

## CURRENT SITUATION AND APPROACHES

The rapidly changing needs and opportunities of today's global market require a higher level of interoperability in data systems to integrate diverse information systems to share knowledge and collaboration among VEs. This includes partnership with the business partners which live in this dynamic environment on a day-to-day basis. Although the core of VE is to effective exchange information, it is not an easy task due to the heterogeneity of information resources [19].

The needs of networked supply chain coordination are associated with innovative processes in which new materials and components are designed. There is a need for interfaces for intelligent applications that will transfer the information into knowledge that can be used in decision making. Employees must be integrated with user-based interfaces with intelligent devices and applications when there is a need for new education methods that will be used in fast information distribution [18]. Panetto and Molina [18] suggest that the future of SCM software lays in malleable and intuitively user friendly software tools that can become an integrating factor, rather than a barrier, to development. Jacobs and Weston [10] predict a greater focus on SMEs in the development path of ERP developers, something that may bring simpler and lighter commercial versions to the market and end up making this kind of solution more attractive.

Manufacturing execution systems are software packages used to manage factory floor material control and labor and machine capacity, and to track and trace components and orders, manage inventory, optimize production activities from order launch to finished goods, etc. Some of the larger ERP-solutions providers have incorporated MES-related capabilities to offer this specialized functionality and fill the shortcomings of traditional ERP-solutions [5]. The integration of ERP and MES requires the easy sharing of information across the systems. MES systems typically take production orders from ERP systems and link quality control, scheduling and material information. Receipt of goods and some low level material handling functionality, including serial number generation for products may be supported as well. Performance dashboards and advanced statistics reporting may be included in the system to provide an overall view of production cells and lines. It is an information bridge between planning systems and manufacturing shop-floor control systems [17].

User interface development has also been discussed in the literature. User interface and general usability of MES software systems is a very important feature. For example, Cooper [3] has patented some transaction control features of a user interface. Later, when web technology has matured, web access systems and mobile terminal access have received increasing interest. There are patented solutions available on this side as well [4]. Lan et. al. [13] propose an integrated manufacturing service system which is a java-enabled solution, together with web techniques, employed for building such a networked service system. Simply integrating ERP with MES not solves the potential issues, such as the time lag between the actual occurrence of shop-floor control data and its recognition in the front office ERP systems at the management level. Broadly speaking, a clear picture of the entire shop floor is not available in real-time. High level managers cannot see what issues exist on the floor and what inventory shortages might impact delivery to the customers.

On the other hand, the information from front office may not be communicated to the shop floor until the MES download the data from ERP. Changes in ERP have been made in real-time do imply the real-time in MES. This disconnection may cause other issues. Due to the lack of capability of adaptability in current ERP systems and MES, new technologies are introduced to improve the capability.

Cloud computing represents a combination of various IT technologies: hardware virtualization, distributed computing (grid computing, utility computing), internet technology (service-oriented architecture, web services, Web 2.0, broad-band networks), system management (service level agreements, data center automation) and open source software. Cloud-based solutions can be described a web-based applications that are stored on remote servers and accessed via internet by standard web browsers [14,24,25].

The main benefit for companies in choosing a cloud-based solution is that almost no local IT resource investment is required. Companies can utilize the flexibility of cloud resources dynamically to meet peak demand without investing in in-house resources. Also, a cloud solution can handle the weaknesses of their current system regarding redundancy and high upgrade cost because Cloud is a virtualization of resources that maintains and

manages itself [22,23].

Nevertheless, most of the challenges and risks are basically security concerns due to the migration from one business model to another. Besides, companies lose the governance over their valuable data and they have to accept that the cloud solution provider will control a quite large number of important issues and areas of their own business process. Some relevant issues are vendor lock-in, compliance challenges, and cloud provider acquisition [11,15].

Cloud computing is already practical in many business applications. Nowadays the major application vendors are actively building cloud-based application infrastructures, exploring relationships with cloud hosting providers.

For manufacturing companies, cloud-based MES solutions allow the standardization of manufacturing sub-processes across multiple plants in many countries. This concept is attractive because it acquires manufacturing assets around the world and leverage best practices internally within the entire organization [8]. However, there are still many challenges connected with bringing MES to cloud. MES tends to be highly industry and process-specific, which means highly customized for a specific process running at specific plants. It needs to be able to quickly change when processes or requirements change. However, customization is still a limitation for cloud-based solutions [15].

To summarize the results of the literature review from cloud technology point of view can be seen that the mentioned requirements have some features, which are not part of standard MES systems and where cloud technology could offer some solution:

- Routing of manufacturing operations may change within the supply chain and the companies that need to access the data may vary from time to time.
- Quality and test data need to be shared between manufacturing partners along the routing.
- The participating companies of manufacturing network may vary from project to project and ability to reconfigure the access should not require IT projects.

Current ERP and MES systems are not very good at this type of fast structural change. Information sharing between partners working together in common projects is actually a typical feature for cloud based social media sites rather than operational manufacturing systems. The concept of linking and sharing data between entities in a similar way would have novelty.

**PROTOTYPING A SOLUTION**

To fulfill the requirements and challenges presented, software architecture is presented to illustrate a potential solution. Although the solution focused on key requirements, it includes new business process and planning, sequencing algorithms, and a new infrastructure based on existing MES technology. If successfully implemented, such a software solution could prove very beneficial to multi-company SME-intensive networks (fig.1).

In the proposed solution, the cloud plays a role as a platform in the evolution of MES. Since cloud computing is already practical at the business application level, it is very reasonable to build MES based on web service and provide a standard for information sharing/transferring environments. Cloud technology will be adopted in order to support monitoring, information exchange and also other real-time interactions.

Andon systems are used when a problem occurs in the production lines and are core elements in the proposed solution. “Andon” is a visual control that is used to notify the status of machines and manufacturing line in the manufacturing process. This concept was first invented by the Japanese for Jidoka (automation in English) and refers to the principle of stopping work immediately when a problem occurs. Andons are used by Toyota and quickly adopted by many Japanese and American manufacturing companies [12,20]. They can be used to control the quality of production and improve the defect detecting processes.

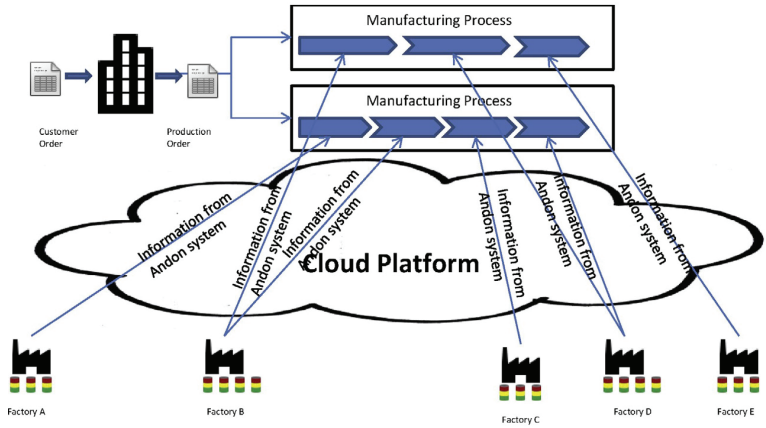


Fig. 1. Integrating ERP systems with MES systems [9]

Most manufacturing companies use ERP or an equivalent system to determine product manufacturing and the production planning process. The proposed solution is used herein to translate this plan into work instruction, and elaborate the method of dealing with real resources and real plant floor execution. The proposed architecture is for a web browser based MES system for distributed (multi-site) production planning and control system. The key features of the system include:

- Support for multi-site manufacturing,
- No installation required-a web based system,
- Connections to external systems such as ERP,
- Tracking and tracing within the entire extended enterprise.

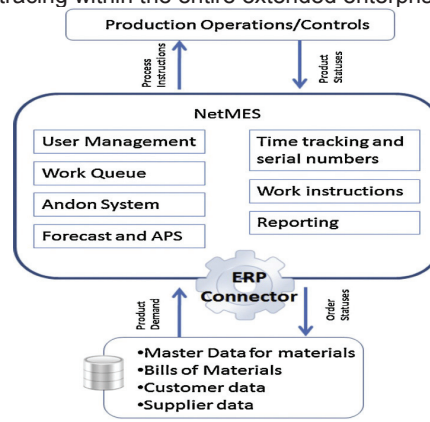


Fig. 2. Key functionality blocks [9]

Figure 2 shows the planned key functionality blocks in the proposed solution: (1) user management, (2) work queue, (3) Andon system, (4) forecast and APS, (5) time tracking and serial numbers, (6) work instructions, (7) reporting and last but not least, (8) ERP connectors.

**CONCLUSION**

A cloud-based MES infrastructure to integrate information exchange between companies has been proposed for distributed manufacturing. The proposed system can

operate in situations where suppliers need to input significant manufacturing related information and provide this to other participants of the delivery along the supply chain. The advantages can be summarized as follows:

- Users only need to install web browser to use this cloud-based solution. It minimizes technical complexities and infrastructure.
- It provides an easier way to supply chain and manufacturing execution and control and it maximizes the benefits of IT systems.
- It provides a flexible platform to integrate different applications.
- Different users can have different customized views to monitor different information.
- It support the decision making process and simplifies the business processes.

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**Докладът е рецензиран.**