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Toward a cloud-based manufacturing execution system for distributed manufacturing

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ABSTRACT

This paper illustrates the needs and challenges for the management of distributed manufacturing in a multi-company supply chain and processes these further as features of new IT systems. Requirements are collected from manufacturing companies and combined with insights from literature in the field of current ERP/MES system drawbacks, advantages, needs and challenges. The findings show that the needs and challenges in data integration inside SME networks are closely related to the limitations of current supply chain solutions. Current ERP-solutions lack extended enterprise support and a shared cloud-based approach. On the other hand, current MES solutions can operate the manufacturing process, but not for distributed manufacturing. As an answer to the requirements, we made a proposal for the core of architecture for next generation of MES solution in this position paper. Moreover, a pilot software tool has been developed to support the needs related to real time, cloud-based, light weight operation.

1. 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 [12]. All these highlight the importance of information technology in integrating suppliers and other partners' firms in a virtual enterprise and supply chain [11]. 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 [2]. 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 [4]. Arend and Wisner [2] suggest that many firms with 500 or fewer employees, i.e. SMEs choose to make SCM part of their strategy implementation, while other SMEs shun it.

The development of the enterprise resource planning (ERP) solution has created an opportunity to manage supply chains within and beyond the organizational scope [30]. This high value-oriented supply chain enables a high level of integration, improves communication within internal and external business networks, and enhances the decision-making process. In this way, the management of VE beyond different partners can be improved.

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 the 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 [18].

Theoretically, ERP can solve the strategic problem at the upper level, and mainly handle internal and external relevant resource issues. Nevertheless, there are many limitations of ERP. It is precisely because of integration that the ERP system provides an industry standard for specific types of business. On the other hand, it also limits the flexibility and lowers the competitive advantage

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of an enterprise. ERP may also limit progress in SCM from the strategic perspective [1].

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 research question addressed in this paper is: *what are the needs and challenges of integration for integrated supply chain coordination for distributed manufacturing networks?* The object of this paper is to present a new system based on current solutions to solve problems of integration of distributed manufacturing networks through VE form by using new technologies and new infrastructure.

Various system solutions are evaluated in this paper. After discovering the limitations and shortages of each solution, new requirements and challenges are summarized from real cases. In attempting to highlight the practical issues, Six cases are analyzed. Interviews and discussions with key managers and operators in these companies are used to collect and assess the information. Each of these companies contains a network of manufacturing supply chains. The case study reveals some important and unique requirements. Consequently, a new cloud-based solution with new infrastructure is proposed to fulfill these market requirements. This solution is named as NetMES.

Our paper has two major contributions. First, we discuss the limits of current software solutions as applied in distributed manufacturing. Second, we give guidelines on how to develop comprehensive software. This new solution integrates both the concept of ERP and MES. We report this empirical solution and provide a prototype to fulfill the gap between practices and academic research.

The rest of the paper is organized as follows. Section 2 introduces the current situation and approaches to managing virtual enterprises. Section 3 describes the method used in this paper to collect data. Section 4 performs an analysis and discusses the case studies. New challenges and requirements of distributed manufacturing networks integration are then summarized. Section 5 presents a solution and a prototype. Finally, Section 6 presents a brief summary and conclusion.

2. Current situation and approaches

2.1. Centralized ERP

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 [35]. Although the core of VE is to effective exchange information, it is not an easy task due to the heterogeneity of information resources.

ERP provides a comprehensive transaction management system that integrates many kinds of information processing abilities and stores data in a single database [1]. In the era prior to ERP, information processing and data were typically spread across several separate locations.

The installation, re-programming and configuration in current ERP-solutions are very complicated processes that take too much time and planning resources. The solutions are usually hierarchical and centralized entities. ERP integrates all up-to-date information in a single application. Theoretically, this single major source ERP can feed SCM solutions. However, current ERP-solutions do not scale up very well to the whole networked supply chain. Indeed, the jointly agreed standards on data integration also delay the implementation of the next generation of SCM-solutions. Different kinds of SCM-solutions are not automatically interconnected, which makes data integration harder to achieve. One of the fundamental issues in networked supply chain coordination is that current solutions do not take manufacturing processes into consideration sufficiently so that lean production would be practically functional [47].

Akkermans et al. [1] highlight four limitations of ERP: (1) lack of extended enterprise functionality; (2) lack of flexibility in adapting to changing supply chain needs; (3) lack of advanced decision support capabilities; (4) lack of open, modular system architecture.

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 [33]. Panetto and Molina [33] 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 [18] 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.

Izza et al. [17] posit that the challenges of EAI-technologies lie in heterogeneity dissimilarities and lack of semantic interoperability. Different applications execute their own data and process models, which leads to different applications not being automatically interconnected. Primarily, supply chain coordination is based on the trust between different actors in a networked supply chain. This highlights the need for the secure data interchange and standardized services between the actors [39].

ERP-solutions should support other solutions and operating systems more extensively. This would lead to the easier execution of integration of different systems and applications [43]. Consolidation of the ERP-software providers will affect the development of ERP-solutions. ERP-solutions are equivalent in the needs of the biggest global companies, but they do not necessarily answer the needs of local SMEs. Universally applicable ERP-modules do not fit to the last detail the needs of local SMEs [18]. The increase of service-oriented solutions will enable the systems to be more easily configured. In the future it will be easier to bring the solutions into services because the modules will be tailored more specifically for certain branches of industries. Future solutions must become more intelligent. Data mining, intelligent tools and expert-systems will contribute to decision making. Simulation will be a significant element in integrated networked supply chain coordination [18].

2.2. Connection between upper level and lower level in the organization

Even though ERP is used to integrate dispersed information, manage all the centralized information and improve the management within the organization, it is more relevant to the upper level (management level) of the organization. However, in many organizations, the detailed and traceable data about production at lower level, such as the shop-floor control, are unavailable. And yet these data are precisely the key cost drivers in manufacturing