X. A CLOUD BASED SOLUTION FOR COLLABORATIVE MANUFACTURING EXECUTION SYSTEMS

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Abstract: In an effort to gain strategic advantage in the global market, to improve Manufacturing Productivity and reduce Organizational Inefficiencies Manufacturing Organizations have embraced Collaborative Manufacturing Execution Systems (MES/C-MES). Collaborative MES is a critical factor in proper functioning of the Ecosystem comprising of the Manufacturer's Supply Chain, Customers and the flow of cash and goods. Cloud Computing provides a unique advantage in rolling out these Strategic Initiatives at a faster pace and at the same time offering greater reliability and higher Return on Investment. This paper explores how Cloud Computing is used to implement Collaborative Manufacturing Execution Systems. In addition to highlighting the advantages we also point out some of the key handicaps with the current state of art.

1. Background

Traditionally Manufacturing Execution Systems focused on the key production Management Areas such as Production Tracking, Process Management, Data Collection, Quality Management, Dispatching Production Units, Resource Allocation, Labor and Performance Analysis [1]. As the Manufacturing Organizations expand and span across multiple sites so do the challenges in accurate and timely information sharing. Similarly the dependence of a Manufacturing Unit on the vendors for reliable delivery of parts and other raw material requires accurate data sharing. The ecosystem comprising of Manufacturing organizations, their customer's and in turn their customers all require accurate information to be shared. Accurate, Timely and secure information sharing is the critical enabler of an efficient supply chain [2]. This gave rise to the collaborative MES model [3] [4]. Manufacturing Organizations strive to reduce costs and increase productivity through these strategic initiatives and increased collaboration. Figure 1 illustrates how the manufacturing productivity has increased every quarter despite the economy.

For instance, one of the biggest overheads is Inventory on hand. Overhead costs due to Inventory and warehouse space can be reduced by several factors if we have a reliable supply chain and Just In time approach to manufacturing. Transportation costs can similarly be reduced through better planning and reduced expedited shipments. Performance can also be improved by proper utilization of the manufacturing assets. Through better accountability and information sharing we could identify the key strengths and weaknesses in the organization. Proper collaboration between the departments enables us to ensure that we have accurate Accounts Receivable for all the goods shipped. Proper Data capture and storage is also required for regulatory compliance.

The collaborative MES model helps address the need for information flow from MES to the various Business Areas. The Business Areas such as those focused on Logistics, Compliance, Procurement, and Customer Relationship Management could leverage timely and accurate information from the areas in traditional MES. If the inner circle in Figure 2 represents the traditional MES, the collaborative MES can be represented by the figure below.

Figure 1: Manufacturing Productivity 2009 to 2013 [5]
3. Challenges faced in Information Sharing

Traditionally the applications serving the needs of various business areas (custom built or bought as an off the shelf product) are deployed onsite. Integrating these applications enterprise wide is an afterthought and limited by the platform capabilities.

In addition to the limitations of the technology platform, there are other design limitations that impede information sharing in these traditional applications such as misaligned Master Data, hard to compare transaction data, no uniform KPI (Key Performance Indicators) and so on.

4. Cloud Computing

Applications designed using the Cloud Computing platform offer a high degree of scalability and typically can run on a geographically independent location. They can typically be accessed from anywhere with internet connectivity. The cloud platform can be leveraged for providing a standardized solution across the enterprise and with some customization across the supply chain ecosystem. Industry working groups such as MESA help create standard models [1] and definitions to provide a standardized vocabulary and definitions.

Cloud Computing due to its inherent architecture lends itself to an application design that makes
information sharing easier. The data in the cloud can be fed into Business Intelligence and Big Data Tools. Google, Amazon, IBM, Oracle Cloud, Rackspace, Salesforce, Zoho, Cisco [2] and Microsoft Azure all provide their solutions for the cloud platform.

Cloud computing services are offered in many different models such as “Software as a Service”, “Platform as a Service” and others.

The pay as you go options typically offered with these services enables customers to get started with low initial investment and low personnel cost. This is also because the cloud based services typically do not require skilled personnel on the customer’s payroll. The services provider pools its resources and the cost is reduced with better utilization of the teams.

5. Leveraging Cloud Computing Solutions for Production Management

The solutions can be categorized as:

a. Off the shelf Solutions offered as “Software as a service”
b. Custom built solutions built on the Cloud Platform

Off the Shelf Solutions could be built using Industry Standards and offered to organization with customizations not necessarily limited to look and feel/branding.

They can also have custom configured business rules, validations and Master Data as necessary.

The Custom Built Solutions on the Cloud platform leverage a highly available infrastructure that they do not necessarily have to maintain.

Both these solutions could be configured so that they can be securely accessed from anywhere.


Production Management Data comprises of data about man, method, machine, material, measures, and environment. Tracking a manufacturing step requires data to be captured either manually or thru’ PLCs (programmable logic controller machines), sensors, tools and various devices that have the ability log data.

Various device communication protocols such as RS232, USB, TCP/IP, CAN maybe used and the devices may span several generations (some of them brand new and others from older generations).

The challenges are to gather real-time data from the devices quickly, reliably and in a cost effective manner. Frameworks such as KEPServerEX provided by Kepware may be used to capture data [7] instead of writing custom code.

The manufacturing targets and the current number of units produced, downtime, waste and other key-process-indicators are invariably monitored in real-time on the shop floor. This helps the personnel to see a live score-card and provides valuable real-time feedback.
7. Data Collection, Monitoring and Controlling: [6] [9]

Raw Data from various sensors in the manufacturing process gives us insight into Equipment and Process Efficiencies. Information sharing helps the Organization arrive at better estimates. It enables the ecosystem and supply chain to plan and predict more reliably. Lessons can be drawn from properly reported Failure modes and their Effects. This helps us to improve productivity.

8. Data Mining to improve Manufacturing Performance: [6] [8] [10]

Data mining of the production data enables us to identify opportunities for further improvement. Some examples of the techniques and approaches used are Neural Networks, Association Rules, Cluster Analysis, Classification and Regression Trees, Feature Selection, General Optimization, Kohonen Networks (SOFM), Logistic Regression and Generalized Linear Models, MARSplines, Naïve Bayesian Classifiers, Optimal Binning, Partial Least Squares, Random Forests, Response Optimization, Root Cause Analysis, Support Vector Machines.

Statistical Models can be built in the Predictive data mining approach. In this case the goal is to identify one or more statistical models that can be leveraged to predict some scenario of interest. An example of this is condition based maintenance (CBM).


The data mining algorithms analyze historical data and create predictive models. These models feed into Decision Support Systems. These tools can be used:

a. Improve placement of the equipment,
b. Improve efficiency by more effective maintenance schedules that prevent downtime, increase equipment yields,
c. Identify error prone materials,
d. Identify error prone steps on the assembly line,
e. Increase safety,
f. Ensure compliance,
g. Increase return on investment, and
h. Meet business objectives.


Standards based clear direction enables all global manufacturing units to follow a unified architecture and facilitates reliable information sharing. Areas of improvement in the manufacturing process are
identified and prioritized. Documenting the current state enables an objective analysis for next phase. The first step is to start capturing the parametric data. With a clear global strategy it is easy to standardize the data capture and storage.

In terms of long term decisions, data mining tools and techniques help identify causal relationships between the inputs and the undesirable events. Trends observed help direct preventive measures thereby avoiding or minimizing losses. RapidMiner, Monte Carlo Machine Learning, Oracle Data Mining, Microsoft’s SQL Server, and STATISTICA Data mining Software are some of the tools used for data mining in conjunction with the convergent IT infrastructure that captures, stores, and secures data from diverse inputs. For successfully realizing the benefits and eliminating the wastes in manufacturing data integrity plays a key role. If the data obtained is unreliable due to technical, process or human factors it will cause the algorithms to deliver erroneous results. It is important that the data integrity is maintained by preventing the bad data from being entered and validating data quality at each step.

10. Advantages

Business can focus on Business

With the cloud based infrastructure and services the organizations minimize the time, costs and efforts typically needed to support the Business Information Systems.

Low Initial Investment and Pay as you go Model

The Pay as you go Model allows Organization to have a low initial investment on the Systems running the Applications, and the organization may only pay for the computational resources used. This frees up the cash flow for other Business Priorities.

Leverage Business Intelligence tools on Enterprise Data to gain new Insights

With the information readily available various tools can be used to gain knowhow for better Business Decisions.

11. Disadvantages

Accessibility where Internet connectivity is poor

Most of the local tasks in a Manufacturing unit require real time inputs. The practical experience has been that there is a very low tolerance for loss in Internet Connectivity to the cloud. Various efforts have been made when implementing cloud based systems to mitigate these problems. This remains an Achilles heel when implementing cloud based solutions in high volume Manufacturing

Security

The cloud based solutions are accessed using Thick Clients as well as thin clients. As with any connected and distributed application architecture it is important to monitor, address and manage any security vulnerabilities that arise from time to time.

Cloud Monopolization: There are few key players in the Cloud arena. Concerns have been raised that this creates a risk of Monopolization.

Legal: Since the data is stored in the “cloud” certain countries have “safe harbor” legal requirements. These have to be met by demonstrating among other things that the personnel data is private and maintained securely.

Noisy Neighbor Problems

Since the cloud based hosting and computing essentially involves sharing of hardware and other resources, it is possible to run into system limitations where some customer’s usage far exceeds than those of the others thereby causing a temporary or extended loss of performance. These have to be monitored and managed.
12. Conclusion

Manufacturing productivities have increased over the years. This has been achieved by implementing certain strategies to reduce costs and improve performance. To reduce costs and improve performance it is very critical that we collaborate and share information accurately and reliably. Collaborative MES describes a Manufacturing model that can be used to achieve this. Cloud computing offers distinct advantages to implement such as model cost effectively.

13. References


7. KEPServerEX framework, (http://www.kepware.com/kepserverex/).


14. Appendix

Abbreviations and Acronyms

- CBM: condition based maintenance
- CMES: Collaborative Manufacturing Execution Systems
- KPI: Key Performance Indicators
- MES: Manufacturing Execution Systems
- MESA: Manufacturing Enterprise Solutions Association (MESA) International is a worldwide not-for-profit community of manufacturing companies, information technology hardware and software suppliers, system integrators, consulting service providers, analysts, editors, academics and students.
- RFID: Radio Frequency Identifications
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