Manufacturer acceptance of cloud services depends largely on the manufacturing industry, nature of the application and size of the manufacturer. Manufacturers can reduce operating costs and gain agility from broader adoption.

Key Findings

- All manufacturers can benefit from cloud computing to collaborate on design efforts, make key business decisions and automate business processes today.
- Small or midsize manufacturers will be quicker to adopt cloud computing as a means of creating, managing, and reusing product and process content earlier than larger manufacturers.
- Consumer goods and high tech manufacturers are adopting cloud applications and services for new product development faster than the aerospace and defense (A&D) and automotive industries.
- Network bandwidth is adequate for most manufacturing-related applications, with some exceptions. Examples of exceptions include engineering analyses involving high-performance computing, such as assessing structural viability of aircraft and crashworthiness of vehicles.

Recommendations

- While data security needs to be addressed, IT and business executives should not allow it to be a major obstacle to cloud adoption. Early experience suggests that the cloud might safeguard intellectual property (IP) better than on-premises applications and databases.
- IT and business process teams must collaboratively define the use cases for cloud computing. In doing so, potential benefits, total cost of ownership and enhancement of existing process capabilities all must be considered.
- IT strategists across the value chain should first be exploring a private cloud as a platform for collaboration and supporting business processes, particularly for geographically dispersed
teams, when successful workflow depends on team members who frequently travel and are responsible for activities in the field, in factories and with partner firms.

Table of Contents

Analysis..................................................................................................................................................2
1.0 Gartner Cloud Computing Definitions..........................................................................................3
2.0 To Understand the Benefits of Cloud Computing, First Understand Cloud Computing Services.........................................................................................................................................................4
3.0 Cloud Computing Tiered Architecture Model for Use in Business Readiness Assessments.......5
  3.1 Gartner Divides Cloud Computing Services Into Six Layered Categories........................................5
4.0 Cloud in Manufacturing Industries...............................................................................................7
  4.1 Major Cloud Opportunities in Manufacturing..............................................................................9
  4.2 Developments Specific to Product Design and Life Cycle Management........................................9
  4.3 Major Challenges................................................................................................................11
Recommendations......................................................................................................................... 11
Recommended Reading.......................................................................................................................12

List of Figures

Figure 1. Cloud Computing Tiered Architecture Model............................................................................5

Analysis

Cloud computing is a major technology trend that has been permeating the IT market over the past few years. It underpins a new approach to IT that enables individuals and businesses to choose how they’ll acquire or deliver IT services, with reduced emphasis on the constraints of traditional software and hardware licensing models.

Cloud computing could have a potentially transformative impact on every aspect of IT among manufacturing companies, including how users access applications, information and business services. Nonetheless, the breadth and depth of the cloud’s impact and the level of adoption over time are still uncertain. That uncertainty is magnified by vendors’ efforts to hype cloud as a differentiator. These high levels of confusion and uncertainty — especially in terms of definitions, how to approach or adopt this technology and the long-term impact on the enterprise — make cloud computing one of Gartner’s top 10 strategic technology trends to address and research, overall.

Manufacturers have tremendous breadth of requirements that can be supported via multiple types of cloud computing support. Current use of “the cloud” spans sales support, HR, logistics, product
development and life cycle management, and manufacturing operations to various degrees. However, there are, and will continue to be, significant differences in cloud adoption among manufacturers, based on the manufacturing industry, the nature of the applications to be adopted and the size of the company.

While this published research focuses on product development and life cycle management, the authors encourage Gartner’s manufacturing clients to also read related research such as "Supply Chain Advisory: Manufacturing in the Cloud Overview," "Impact of Cloud on Supply Chain Management" and "Supply Chain Advisory: A Cloud Overview" to get a more complete perspective of cloud computing opportunities and priorities. Those publications provide complementary perspectives that assist in planning a cloud strategy, particularly for planning supply chain and manufacturing operations support.

1.0 Gartner Cloud Computing Definitions

Gartner defines cloud computing as a style of computing where scalable and elastic IT-related capabilities are provided "as a service" to customers using Internet technologies. The business criteria for adopting cloud-based software services are similar to the criteria used for selecting any outsourcing and hosting of applications operated and managed by external service providers. When considering the appropriateness of a cloud as an IT service delivery model, manufacturers should first determine the extent to which that component of the business differentiates the products or provides other types of competitive advantage. In those cases, manufacturers will typically not adopt a cloud platform. For example, most manufacturers are reluctant to manage new product development data with cloud-based applications.

Manufacturers more readily adopt cloud computing for well-characterized activities with workflows that are relatively mature, better understood and perceived as less differentiating, yet the "elasticity" of access to applications ebbs and flows with demand for those activities. For example, manufacturers increasingly employ cloud-based computing for logistics, HR functions and sales support. Large enterprises are less likely to use cloud as a service delivery model for mission-critical applications, such as those used to develop sensitive IP. They will, however, integrate cloud services into those mission-critical internal applications and systems.

Cloud computing models that manufacturers should assess include:

- **Public cloud** — An IT capability as a service that providers offer to consumers via the public Internet
- **Private cloud** — An IT capability as a service that providers offer to a select group of customers or value chain partners.
- **Internal cloud** — An IT capability as a service that an IT organization offers to its own business (subset of private cloud)
- **External cloud** — An IT capability as a service offered to a business that is not hosted by its own IT organization
- **Hybrid cloud** — IT capabilities that are spread between the internal and external cloud
2.0 To Understand the Benefits of Cloud Computing, First Understand Cloud Computing Services

Gartner defines cloud computing (the cloud) as "a style of computing where scalable and elastic IT-enabled capabilities are delivered as a service to external customers using Internet technologies." Cloud-based computing has the following characteristics that can be attractive to manufacturers:

- **Service-based** — The categories of enterprisewide applications that support customer engagement, product life cycle support, manufacturing operations, supply chain activities and the back office are expensive to implement, maintain, upgrade and support. Such cloud-based applications delivered as services can eliminate planning and implementation costs that can be from two to seven times the original cost of the software, based on surveys conducted by Gartner with 62 manufacturers.

- **Scalable and elastic** — The business fortunes of manufacturers ebb and flow based on economic, political, climatic and cultural factors. Also, the demand for particular categories of software adjusts according to the demand for various activities, based on customer demand, supply chain factors, and the state and nature of product life cycle activities. Cloud enables manufacturers to use various classes of applications based on these demands.

- **Shared** — Cloud can use IT resources with maximum efficiency because the underlying infrastructure, software or platforms are shared by all of the users. This suggests that manufacturers can maintain the software infrastructure at lower cost for larger numbers of users.

- **Metered by use** — This means that manufacturers can potentially have greater flexibility in controlling costs, based on expansion and contraction of software use.

- **Mobile device enabled via the Internet** — Mobile devices offer manufacturing roles across marketing, product development, manufacturing operations, sourcing and customer services unprecedented flexibility to access the latest content in real time for faster informed decision making.

Cloud services can be attractive because they can potentially:

- **Reduce costs** — Due to reduced or eliminated cost of servers, data center space, maintenance fees, electricity/power and IT staff; also allows deferral of capital costs.

- **Increase agility** — Easy-to-use, on-demand development tools, with programming environments, can be made quickly available to the business, thus increasing agility and responsiveness.

- **Increase flexibility** — Cloud computing services can be called quickly when needed, and can grow or shrink according to need. This makes cloud computing well suited for sporadic or seasonal workloads, and also to supplement traditional systems when demand for computing peaks.

It is also important to understand the various tiers of cloud computing services and where each can be deployed since cloud computing is not necessarily suitable for all business processes or applications.
3.0 Cloud Computing Tiered Architecture Model for Use in Business Readiness Assessments

Gartner has designed a template diagram to help our clients better understand cloud computing services. In the high-level pictorial view of the template diagram in Figure 1, cloud services are broken into six distinct categories.

If manufacturers and retailers with private-label brands understand the services in each of these tiers, it will help them evaluate which business processes will benefit best from each of the tiers and, consequently, assist in formulating and implementing their cloud-adoption strategies.

Figure 1. Cloud Computing Tiered Architecture Model

3.1 Gartner Divides Cloud Computing Services Into Six Layered Categories

1. **Cloud system infrastructure services** — System infrastructure services are the most basic and fundamental form of cloud computing services, and they parallel the infrastructure and data center initiatives in IT today. System infrastructure services include system-level capabilities, such as server/computing, server operating system, client operating system, storage or networking, on which the consumer can run a variety of applications. Although virtualization is a key enabling technology, not all such platforms depend on a virtualized architecture. The term "cloud system infrastructure services" maps to the National Institute of Standards and Technology's (NIST's) "cloud infrastructure as a service (IaaS)" term.

2. **Cloud application infrastructure services** — Application infrastructure services parallel the application infrastructure, middleware and development environments used in-house. Services include development, integration and business process management as a service.
minimalist approach is for vendors to simply provide the ability to run enterprise application software in the cloud on a shared system infrastructure. However, optimized cloud application infrastructure services must be built to exploit Web-centric architectures and global-class design principles. These services should also support multitenancy and enable the development of multitenant applications. The term "cloud application infrastructure services" maps to NIST’s "cloud platform as a service (PaaS)" term. Do not confuse PaaS with application platform as a service (aPaaS). Gartner has described a subcategory called "application platform as a service," where vendors provide integrated development and runtime environments analogous to application server platforms.

3. **Cloud application services** — Application services are applications designed based on global-class principles, and delivered as a service via Internet and Web-centric architectures to a browser or rich Internet application (RIA) front end. Cloud application services usually require the creation of a multitenant architecture where one application supports many firms, but provides a unique view for each. Customizations, extensions and data are isolated among tenants and firms by default, but may be selectively shared. The term "cloud application services" maps to NIST’s "cloud software as a service (SaaS)" term. However, the Gartner definition of cloud application services is narrower than the NIST SaaS category. SaaS in the NIST model would generally include information services, ecosystem management and security services, as well as many business process services described below. While using SaaS as shorthand for all these categories is useful to identify a simplified three-layer model, we believe there are sufficient differences between the capabilities offered at these levels to deal with them as separate, but related, entities.

4. **Cloud information services** — Information services offer search services or other mechanisms to provide access to external data or content. Unlike other cloud service categories, information services do not require the consumer to move any of its data or business process logic into the cloud. The information service simply delivers information that already exists in the cloud. This information may be consumed by an internal enterprise application or mashed with other services to create a composite application. Information services are most typically accessed via a simple Web-based application programming interface (API) or delivered as feeds using RSS/Atom. There is no corresponding separate layer in the NIST terminology. Generally, what Gartner refers to as information services are included in SaaS by those using the NIST model.

5. **Cloud business process services** — Business process services refer to any business process (for example, payroll, printing or e-commerce) that is delivered as an elastic service via the Internet with access via Web-centric interfaces and Web-oriented architecture (WOA) access mechanisms. These services are distinct from cloud application services. Cloud application services may include business process logic as an aspect of the service being consumed. For example, using a cloud application service for sales force automation will likely include business process workflows. The distinction is that a business process service includes some business process activity that is performed by the service provider. The provider performs some real-world activity (for example, order fulfillment) and/or interfaces with another company on behalf of the service consumer (for example, ad placement). There is no corresponding layer in the NIST terminology. While the exposed portion of a business process service is considered by many to be a form of SaaS, Gartner believes it is important to view this as a distinct category.
6. **Cloud ecosystem management and security services** — Ecosystem management and security services refer to services that manage the access, configuration, consumption, delivery and security of cloud-based services and information, as well as the service-level agreements associated with the services. The primary and direct business values of cloud services are provided by the application, information and process services, insofar as they are the services that touch the end user directly. Ecosystem management and security services deliver value by making it easier, less risky and more cost-effective to use other cloud services. These services are critical for consumers who plan to consume and integrate multiple cloud services from multiple vendors or build applications in the cloud. Often, some level of management and security service is included as part of one or more application infrastructure services. There is no corresponding layer in the NIST terminology, but since these are generally service-based versions of software, they would generally be included under the SaaS category for NIST. Since introducing this terminology, Gartner has also begun to talk about these capabilities as part of the ongoing research on cloud service brokerages.

4.0 Cloud in Manufacturing Industries

While manufacturers have been readily adopting SaaS offerings for sales support, logistics and back-office needs, such as managing HR, they have been slow to adopt cloud-based applications for new product development and life cycle management.

The rate at which manufacturers adopt cloud-based applications for product design and life cycle management depends on the nature of the industry, the nature of the applications, and the size of the manufacturer. Overall, Gartner expects small-to-midsize manufacturers in all manufacturing verticals, including aerospace and defense, automotive, consumer goods, high tech, and life sciences to adopt cloud-based product life cycle management (PLM)-related SaaS applications faster than larger manufacturers in those same industries. Although large manufacturers have greater resources and bandwidth than small or midsize businesses (SMBs) to evaluate implications and implement change management associated with the cloud, they are already heavily entrenched in on-premises applications. So, the investment to make the changes would be significant. Also, they have cultivated heavily customized product development practices and processes over many years. This is particularly true for manufacturers of complex products such as automobiles, aircraft, ships, heavy agricultural and construction equipment, etc. Migrating these customizations, most likely to a private cloud, would be a considerable investment. Adequate performance of design and engineering applications remains uncertain since it depends on the nature of the design effort. And, executives of large companies express concern about security of sensitive design content.

Many SMBs that perceive the potential value of PLM have been discouraged by the costs of getting started. Gartner has spoken with several SMBs that perceive SaaS-based PLM software as a more cost-effective means of adopting such software. As SaaS-based PLM proves itself, Gartner expects cloud-based PLM services will go mainstream for SMB manufacturers by 2016.

The nature of the manufacturing vertical will also influence the rate at which they adopt cloud-based product design and life cycle management applications and which applications they adopt. Industries such as aerospace and defense, automotive, shipbuilding, etc. are likely to adopt cloud-based design and PLM applications later than manufacturers in sectors that have been embracing
PLM more recently such as consumer goods producers and high-tech companies. The earlier PLM adopters have already made heavy investments in on-premises PLM software, which involved heavy customization of complex processes. Also, they have expressed greater concerns about IP protection and security risks (see Note 1). Although design and PLM software is likely to remain on-premises through at least 2017, Gartner expects that these manufacturers will readily adopt SaaS applications as private clouds to support field service and provide analytics for continuous product and process improvements. Consumer-facing industries, such as automotive, are likely to adopt SaaS applications, business processes and application services to collect and analyze data regarding market sentiment for new product ideation. Also, the automotive industry is already adopting cloud applications readily to support information and communications technologies in vehicles.

Although newer adopters of PLM software such as consumer goods manufacturers, pharmaceuticals companies and high-tech firms also express concerns about IP protections, several have expressed enthusiasm to adopt the cloud for market sensing, idea generation and management, collaborative conceptual design, etc. These anticipated "earlier adopter" industries will be compelled by agility and convenience of cloud-based applications to address the business pressures of short "windows of opportunity" to sell differentiated products in markets that move fast and the products have short life cycles. IaaS also offers the data storage and processing speed to handle this increasing complexity of more personalized messaging to particular customer segments across a wide variety of means, including social networking on mobile devices. Yet, even among faster-moving consumer goods companies, the marketing departments in some of the larger ones still prefer on-premises or hosted applications to sense market demand and preferences due to marketing process complexity requiring customization, data integration requirements and advanced treatment of analytics.

Supplier collaboration and logistics are activities seeing rapid update of the cloud among manufacturers. Vendors, such as Camstar, iCiX and InfinityQS, all offer supplier quality management system functionality via the cloud. According to a Gartner survey of 275 supply chain decision makers, almost half of supply chain management (SCM) decision makers want to adopt an IT platform strategy other than on-premises. IaaS is the most likely infrastructure to support supply chain options that might be hosted. Regarding rate of adoption, the supply chain survey suggests that 17% of the 257 survey participants will adopt the cloud to deploy supply chain software by 2014, doubling the number of users since 2008.

While use of cloud-based applications for manufacturing operations will grow, not all mission-critical facets of manufacturing operations will embrace cloud infrastructure and platform services. For example, while it’s quite feasible to envision using SaaS and the cloud to deliver a manufacturing execution system (MES) to manufacturers with job shop or assembly operations that require simple data collection requirements, doing so for other scenarios that require high-speed, automated data collection remains a stretch. The operational requirements (such as high fidelity) for these systems make it difficult to share resources across the heterogeneous software and operational technology landscapes in the production environment.
4.1 Major Cloud Opportunities in Manufacturing

- IaaS is an obvious place to start. Product development, engineering analysis, and test and production environments will continue to evolve on cloud platforms. Private cloud deployments can squeeze out IT infrastructure costs.

- Engineering collaboration, decision making and change processes emerging today will become mainstream by 2016.

- Business process automation via the cloud is emerging today, and will become mainstream by 2017.

- Plant and product maintenance, repair and upgrade activities will become mainstream by 2017.

- Cloud computing for digital marketing will become mainstream by 2017.

- Product data management support for SMB manufacturers will become mainstream by 2017. Such support will become mainstream for large manufacturers beyond 2020.

- Cloud deployment for supply chain activities is emerging today, and will continue to grow.

- Engineering analysis via the cloud is emerging today, except for large or complex simulations that typically require supercomputing.

- Global data synchronization to improve master data management (MDM) is another key cloud opportunity. This is particularly relevant to the future of enterprise-centric PLM. Integrating with data pools and repositories reduces errors and lubricates commerce between manufacturers and their trading partners.

- Quality management systems are increasingly popular with small manufacturers that need "packaged quality compliance" approaches or supplier quality systems.

- Environmental, health and safety (EH&S) systems — SaaS-based applications — are well suited for companies where there are minimal IT resources and insufficient regulatory monitoring staff to maintain the systems and keep them current.

- Operations intelligence and manufacturing performance management SaaS offerings have been advancing. The next sections offer examples demonstrated at the SAP Insider event held during March 2012 in Orlando, Florida.

4.2 Developments Specific to Product Design and Life Cycle Management

As cloud services continue to evolve, software providers are becoming increasingly effective at delivering SaaS and PaaS-based product design and life cycle management capabilities. Since 2010, software providers are accelerating the number of SaaS and PaaS-based services available on the market. A few notable examples include:

- During February 2012, Autodesk released its Autodesk PLM 360 SaaS. Within the context of supporting multiple complementary PLM, Autodesk architected it to conceivably expand as a
PaaS for PLM needs. Autodesk also promotes SaaS-based design, collaboration and visualization offerings.

- Dassault Systemes offers multiple design, collaboration and visualization SaaS offerings, hosted on Amazon IaaS.
- The service provider Atos enabled Siemens’ Teamcenter PLM software as SaaS.
- Aras promotes cloud support for its PLM offerings, as well as making them open source. Manufacturers can download Aras PLM software, evaluate it and then decide to access it via SaaS.
- Vuuch applies social networking principles via the cloud to connect engineers and other manufacturing roles for problem solving.
- Inforbix leverages the cloud to extract data from heterogeneous sources for analysis and decision making.

Other recent manufacturing-related cloud opportunities, not necessarily specific to product design and life cycle management, include:

- A new company, Kenesto, targets manufacturers to adopt its ability to define, design and automate business processes via the cloud.
- Aspen Tech’s SaaS-based token licensing model for its engineering suite of applications is an example of engineering-centric process design tools being offered on a pay-per-use model.
- At the most recent SAP Insider event held during March 2012, SAP development partners demonstrated cloud-based applications to monitor plant performance and address maintenance and repair issues.
- EH&S providers, such as 3E, Actio and IHS, use cloud-based delivery models to provide managed regulatory content, such as chemical property data, handling instructions, material safety data sheets (MSDSs) and other variables required for demonstrating product compliance.

Increasingly, engineering analysis is also becoming accessible via cloud. A few manufacturers have reported success at running multiple engineering analyses, simultaneously, to do parametric design analysis. Instead of running the analyses serially on a single processor, they run the analyses, simultaneously, on multiple processors available through IaaS — each analysis having different combinations of design parameters. By running these analyses in parallel, they save time achieving an understanding of how design choices such as materials, dimensions and inclusion of product features affect product performance. This can significantly reduce design cycles. However, the cloud is not yet ready to handle complex analyses that typically require high-performance computing. Examples include aircraft structural analysis, analysis of large ships or automobile crashworthiness. Those calculations can involve inverting matrices with millions of degrees of freedom, many times. Network bandwidth remains a constraint to orchestrating adequate performance — even with multiple processors churning on a single problem. Yet, as the history of IT suggests, IT advances will likely relieve these bandwidth constraints over time.
4.3 Major Challenges

- Many manufacturing organizations perceive cloud-based applications, especially public cloud offerings, as a security risk for IP, such as scientific innovations, software logic that deliver product function, and sensitive product-related and process-related data. This is particularly true in A&D industries.

- Manufacturers express concern over the ability to enable and maintain software customizations via the customized software they currently use with on-premises software.

- Cloud-based network bandwidth for demanding design, engineering and data management applications involving large files (terabytes or even petabytes) remains inadequate for important use cases in industries such as A&D and automotive.

- The cloud has significant implications for defining and managing business processes that remain to be understood.

- Manufacturers have yet to plan for the IT governance implications of cloud-based services.

Recommendations

IT managers responsible for design, and PLM software strategy and business leaders, should be:

- Planning to adopt cloud-based applications for design and engineering collaboration today, particularly for design reviews, approvals for engineering changes and decision making that affects field activities. Run pilots to understand company-specific opportunities, challenges and governance requirements.

- Studying and selecting acceptable lightweight visualization formats, such as JT, 3D XML, .RH and Design Web Format (DWF), that can support the cloud-based activities recommended above. Increasingly, these lightweight visualization formats will become central to expanded use of 3D by manufacturers, and their presence in corporate databases will grow rapidly.

- Experimenting with new cloud-based opportunities for manufacturers such as business process automation, social networking that supports engineering decision-making and plant maintenance applications. Adopt them as appropriate, based on the evaluations and as the business gains confidence in how to use and manage them.

- Increasingly adopting cloud-based applications that support supply chain activities as manufacturers adopt and validate those capabilities.

- Marketing departments should adopt a cloud-based strategy to monitor customer sentiment and run digital marketing campaigns as the performance and flexibility of cloud computing increasingly enable manufacturers to provide personalized offers and analyze shopper activities in real time.
Recommended Reading

Some documents may not be available as part of your current Gartner subscription.

"Autodesk’s Cloud-Based PLM Offering Is Taking Shape"

"Predicts 2012: Product Design and Life Cycle Management"

"Supply Chain Advisory: Manufacturing in the Cloud Overview"

"Impact of the Cloud on Supply Chain Management"

"Supply Chain Advisory: A Cloud Overview"

"Predicts 2012: Demand Sensing Will Be Key to Success and Growth in Consumer Goods Manufacturing"

Note 1 International Traffic in Arms Regulations (ITAR) Affects U.S.-Based A&D Companies

ITAR is a set of United States government regulations that control the export and import of parts, material and content judged as sensitive to United States security. Manufacturers perceive cloud-based applications as more vulnerable to breaches in ITAR security provisions. Defense-related companies in other regions of the world also prioritize security.
GARTNER HEADQUARTERS

Corporate Headquarters
56 Top Gallant Road
Stamford, CT 06902-7700
USA
+1 203 964 0096

Regional Headquarters
AUSTRALIA
BRAZIL
JAPAN
UNITED KINGDOM

For a complete list of worldwide locations, visit http://www.gartner.com/technology/about.jsp