The Economics and Strategy of Manufacturing and the Cloud

MASS PRODUCTION DATES BACK THOUSANDS OF YEARS TO THE BABYLONIANS, WHO PRODUCED FIRED BRICKS USING MOLDS. Since that time, there have been four major waves of manufacturing technology. Some count the first three waves as water and steam power; electric power; and computer power, such as manufacturing resource planning and inventory control systems.[1] Others count them as lean manufacturing, such as the Toyota Production System; outsourcing; and automation.[2] In either case, the fourth wave, often called "Industry 4.0," involves the constellation of modern digital technologies, such as the cloud, big data and analytics, and cyberphysical systems and the Internet of Things.

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In this fourth wave, the cloud can play a role in many different processes for companies that design, engineer, manufacture, and/or distribute products. Physical designs can be efficiently simulated and analyzed via clouds, say, through finite element analysis for stiffness or for thermal transfer characteristics, or electronic circuit design simulation. There, the usual economic benefits associated with software as a service or elastic capacity for infrastructure as a service in the presence of intermittent demand hold; the specifics will vary by manufacturer and its application profile.[3]

Materials requirements, manufacturing resource, or enterprise resource planning systems can be run in a single instance or on a multitenant basis at a remote datacenter, supporting numerous manufacturing locations. Databases, such as parts or supplier management, can be consolidated. In such cases, a single investment in datacenters, colocation space, physical servers, or software licenses to support multiple facilities can achieve economic benefits.

However, to merely focus on the economics of cost optimization via the cloud would miss a bigger picture—namely, the strategic benefit that cloud-connected products and cloud-centric manufacturing and distribution processes can create.

Expanding one's viewpoint beyond a single factory or company, suppliers, sister factories, downstream plants, warehouses and logistics centers, and distribution channels can all be coordinated through the cloud, leading to economic benefits in terms of resource utilization, time to market, inventory holding costs, and customer satisfaction. In addition, unique requirements for particular industries, such as chain of custody for pharmaceuticals, can be managed, leading to economic and strategic benefits for manufacturers, thanks to a reduction in counterfeiting, health benefits for patients, and broader benefits to society through a reduction in the spread of disease.

Product sales can be facilitated through cloud-based customer relationship management software. Distribution and logistics companies can coordinate via the cloud. One firm operating in this space, Xvela, enables ocean carriers (shipping companies) and terminal operators (ports) to coordinate ship arrivals, unloading, loading, and departures by optimizing across geographic locations based on ship locations, weather forecasts, bills of lading, container stacking, and so forth (https://xvela.com/solutions.html).

As with any industry these days, an increasing proportion of firms are moving some, or most, of their workloads to the cloud, ranging from mundane applications such as email and payroll to sophisticated applications such as genome sequencing. For example, Johnson & Johnson has targeted such a move for 85 percent of its applications, and Coca-Cola might reach 50 percent.[4] GE has famously stated that it's "all-in" on public cloud.[5]

In addition to all of these traditional and emerging applications for the cloud in manufacturing and supply chain processes, product companies can use a number of innovative mechanisms to exploit the cloud to create value, where such value can be defined in terms of improved customer experience and thus total customer lifetime value and profitability, enhanced customer stickiness and thus lower churn and acquisition costs, referral marketing and thus greater ratios of sales to selling, general and administrative expenses costs, and the like.

Product-Service System Functionality

Increasingly, products today aren't really products, but rather product-service systems, where a product ties a network to cloud-based functionality. Amazon's Kindles and Kindle apps get (electronic) books downloaded to them over the air, iPods get songs, smart TVs and Netflix apps receive digital movies streamed from the cloud, smartphones and tablets get apps, and so on. But such products don't only benefit from cloud connections for ordering and extensibility; often, product functionality depends on the cloud. Smartphones don't perform their own Web searches, but rely on cloud-based search query response functionality. Alexa, Siri, Cortana, Google Now, and similar functions occur in the cloud, even though they might appear to be device-resident functions. Amazon Dash buttons look like small products, but they reorder items such as paper towels and laundry detergent via wireless networks and the cloud.[6]

Product-Service System Services

Not only core product functions, but also support services can be provided via the cloud. "Help" used to be provided via a printed manual, then one encoded on a CD or DVD. Today, product help functionality is typically provided over the Web. But text-based help is evolving into chatbots and video concierge services. For example, the Kindle Fire has a "mayday" function, where tapping an icon initiates a video concierge service. A remote support agent can see your screen (with your permission) and draw on it, while you can see the agent in a video window.[7]

Remote Access

When manufactured products are connected over networks to the cloud, data they've acquired can be accessed remotely, normalized, archived, aggregated, and analyzed. One obvious example is weather sensors, for weather reporting and forecasting; another is video monitoring and surveillance devices. A video stream is captured (say, in the baby's room or a convenience store) and sent over the Internet to the cloud. From there, it can be forwarded to a remote device such as a smartphone to be viewed in real time (say, to make sure the baby is still asleep), to be archived for later review in the event of a crime, or a combination (say, in a "safe city") to track the movement of a suspicious vehicle.

Remote Control

When manufactured products are connected over networks to the cloud, not only can data be accessed, but the devices can be controlled. The (connected) Nest Learning Thermostat is an example. Although it's autonomous and smart (that is, adaptive), it can also be controlled remotely. Consequently, it will maintain a house's temperature by itself, but it can also adjust the temperature so your house can be cooled in time for, say, an unexpected early arrival from a trip.

Such remote access and control capabilities aren't only a matter of convenience, they can also improve cost and safety. For example, a robot can be sent into a nuclear plant cleanup site, or mining operations in remote sites can be conducted from an area closer to civilization.

Data Aggregation and Analysis

The cloud can be a data aggregation point for products with sensors, such as weather stations. Although each station collects local data, data to feed weather forecasting models or provide a national weather map must be aggregated across a wide area to be of use. Earthquake seismographs are another example. These have traditionally been dedicated devices, but now data can be acquired from the accelerometer typically found in smartphones today. A single tremor might be a mere shake of the hand, but if it occurs across many smartphones in a spreading radius, it could signal an earthquake.[8]

New models for data aggregation, control system distribution through actuators, and distributed queries evolve a simple bipolar model of a cloud at one end and devices at the other into a multilayer model that might include:

- a single centralized instance at the top layer;
- multiple distributed locations across multiple regions in a second layer;
- the fog or cloudlets, that is, a dispersed cloud, at the next layer; and
- ultimately, a device, sensor, and/or actuator layer.

Several initiatives have examined how best to utilize a multilayer approach, optimizing or trading off various characteristics—runtime efficiency, response time latency, processing power differentials, and data transport costs. One such example is the cloud-edge-beneath framework, wherein not only can data be aggregated and move upward to the cloud, but application components can migrate down to be closer to the data.[9]

Predictive and Preventive Maintenance

Such data—captured, aggregated, and analyzed—can be used for predictive maintenance. GE GEnx jet engines (www.geaviation.com/commercial/engines/genx), for example, have 20 or more sensors monitoring and measuring data such as oil pressure and rotation speed as frequently as 5,000 times per second.[10] The data can be centrally aggregated and analyzed to build predictive maintenance models. These models can then be used to take an engine out of service before it develops a problem—for example, while a jet is at an airline's airport hub, where it can conduct the required maintenance, rather than at a foreign destination with limited capabilities. This reduces maintenance cost, improves maintenance quality, and increases "time on wing," that is, engine availability for airlines' revenue-generating flights. Similar approaches can be used for manufacturing processes, enabling predictive maintenance of factory equipment.

Product Performance Optimization

When products connect to the cloud, their performance can be optimized. One example is John Deere's Machine Sync (www.deere.com/en_US/products/equipment/ag_management_solutions/guidance/machine_sync/machine_sync.page), which agricultural equipment, such as grain combines, use to traverse optimal paths through an irregular field while ensuring complete coverage. Such a path can ensure that areas of the field aren't missed and overlaps are minimized.

Product Design Optimization

In addition to improving product performance in real time, products connected to the cloud can have their performance improved over the longer term. This is because when products connect to the cloud, usage data can be collected and analyzed. Such data can be used to enhance the product itself or processes associated with it. For example, a cable company can collect fine-grained data on remote control usage so as to improve the device's layout. Even virtual products, such as webpage or application interface designs, can be monitored as to how they're used—for example, patterns of mouse moves or clicks or touchscreen swipes or taps—to improve the virtual layout.

Process Improvement

It's not just products whose performance can be improved in real time, but also the processes that these products resource and enable. For example, smart, digital, connected refrigerators can be used to monitor the "cold chain" of vaccine delivery, from a pharmaceutical production facility to, say, a developing country. Because vaccines lose their efficacy and can even become dangerous if left unrefrigerated, refrigeration must be maintained. However, frequent power outages can make this challenging. In addition to helping ensure that any particular vaccine shipment is kept cold, data collected from such refrigerators can be used to identify problem areas of the cold chain, thus not only protecting a particular shipment but also improving the end-to-end delivery process.[11]

Interproduct Coordination

Instead of optimizing merely a single product's performance, multiple products can work in concert. In GE's Digital Wind Farm (www.gerenewableenergy.com/wind-energy/technology/digital-wind-farm.html), turbines interact with each other through real-time data collection and predictive analytics to optimize each other's performance. Data from a single wind turbine on the exact direction to face or the angle of attack of its blades can be shared with another wind turbine to maximize power-generating capacity, potentially increasing annual energy production by double digit percentages. John Deere's Machine Sync can optimize a path for not only a single piece of farm equipment, but two or more.

Product Network Optimization

Product instances aren't always independent communicating entities, such as wind turbines, but can interact with each other in more complex ways, as with a railway network, where one train might block another one heading the opposite way on a single section of rail, or might be blocked by one in front, as when an express train is blocked by a local one. Optimizing throughput and average speed in such a network is an NP-complete problem best handled by a heuristic running centrally that acquires location information and status from each train and then coordinates each train's acceleration, deceleration, or routing. An example of a system that does this is GE's (railway) Movement Planner System (www.getransportation.com/railconnect360/network-operations/movement-planner-system), whose modules model the rail network, acquire real-time status data, and optimize and route traffic.

Intraportfolio Coordination

Devices needn't be homogenous, as in a wind farm or set of trains. Instead, different product elements within a portfolio can coordinate with each other through a messaging infrastructure. For example, John Deere grain combines interact with John Deere grain carts using Machine Sync. The combines reap the grain, say, from a wheat field. The grain from each combine is then fed into a cart, which, when full, drives off to a silo or waiting truck and is replaced by an empty cart. The coordination between the combine and the carts is closely choreographed, as they must drive exactly side by side, pause simultaneously, execute turns, and so forth.

Multivendor Product Ecosystems

Products need not be part of one vendor's portfolio, but can be part of a designed or organically evolving interoperable ecosystem. For example, Nike+ products (www.nike.com/us/en_us/c/nike-plus) use a unifying principle—NikeFuel (https://developer.nike.com)—and a logically centralized data aggregation, analysis, and archiving point in the cloud with defined APIs and a variety of software development kits. Not just Nike products, but other elements of a multivendor ecosystem work together. This includes other activity trackers, such as Wahoo Fitness products; coaching applications, such as those that run on Microsoft Nike+ (Microsoft Xbox) Kinect; and body fat analyzers, such as the Withings Smart Body Analyzer. This family of interoperable products monitors activities and measures outcomes.[10]

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Network-Enabled Product Upgrades

When products connect to the cloud, they can be upgraded over the air. A good example is the Tesla Model S all-electric vehicle. The car was originally manufactured with various physical elements such as cameras, radar, and ultrasonic sensors. However, an over-the-air software upgrade enabled those sensors to be utilized for collision avoidance and increasingly will enable autonomous vehicle functionality, such as the Tesla Autopilot (www.tesla.com/presskit/autopilot).

Short of completely new functionality, sometimes products can gain a performance improvement via the cloud. The Nest Learning Thermostat 4.3 software upgrade, for example, offered enhanced algorithms to reduce energy consumption by a projected 6 percent.[12]

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New Pricing and Business Models

Connecting products to the cloud enables new business models. For example, American Family Insurance provides Nest Protect smoke detectors to its customers at no charge. Normally, a company would *raise* its rates to recover the cost of an added expense such as this. Instead, AFI *reduced* its premiums. The reasons are straightforward: connected smoke detectors can be monitored to ensure that they're operating properly, and, in the event of a fire, the fire department can be called more quickly, reducing the damage, and thus the average size of the claim. In short, a win-win.[13]

Usage monitoring can also help enable new business models. For example, because homeowners might have difficulty paying a large upfront charge for solar panels, SolarCity offers free solar panel installation (www.solarcity.com/residential/solar-ppa). Homeowners "pay" for the panels based on how much electricity they actually use, determined through remote monitoring of the panels. In this way, a large upfront capital expense for private, dedicated equipment is converted to a metered, pay-per-use fee, just like for an electric utility.

This type of monitoring can be much richer than a single metric such as kilowatt hours. For example, some automobile insurers are utilizing connected vehicles to enable pay-as-you-drive or usage-based insurance. Traditionally, auto insurance has entailed underwriting premiums based on backward-looking or coarse-grained information such as age, gender, education, and prior claims or tickets. Now, a customer can be charged a premium for every mile or minute they drive, based on factors such as miles per hour over the speed limit, distance to the next vehicle, frequent lane changes, weather, roadway congestion, and whether a section of highway is accident prone. Determining charges, and providing real-time customer visibility into rates, couldn't be done without connecting the vehicle to the cloud.[14]

Connected Services

It's incorrect to conflate the Internet of Things with products. Although things are products, today's connected services are enabled by physical entities that connect to each other and to the cloud. Consequently, we can't just think of manufacturing in terms of products, but also in terms of creating smart, digital, connected things, embedded in connected services.

For example, connected healthcare uses medical diagnostic equipment such as X-ray machines and computed tomography scanners, and, increasingly, connected surgical equipment, such as surgical robots, and connected implanted devices, such as pacemakers. Services can extend to a very small scale, such as through Proteus Discover (www.proteus.com/discover), which includes the Proteus Pill, a pill that has a safe-to-ingest microscopic wireless connection to report that it has been taken, together with a wearable patch and an app. As a result, patients can be reminded to take their medication if they forget.

THE CLOUD CAN PLAY A ROLE IN VIRTUALLY EVERY MANUFACTURING AND RELATED FUNCTION AND PROCESS THERE IS: DESIGN, ENGINEERING, SALES, MARKETING, MANUFACTURING, AND SO FORTH. Beyond computerization of business and manufacturing processes, many different benefits can arise when such manufactured products become smart, digital, and connected to the cloud, enabling not just connected products, but also connected services and connected product-service systems.

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