Artificial Intelligence, Automation, and Manufacturing

Future in a Global Economy

Pramod P. Khargonekar
University of California, Irvine

CNMI Summit 2018
Automation: The Next Generation of Lean
June 7, 2018
Global demographic shifts will drive the coming decades.

Figure 2. Population of the world: estimates, 1950-2015, and medium-variant projection with 95 per cent prediction intervals, 2015-2100

Figure 1. Number of persons aged 60 years or over by development group, from 1980 to 2050

Table 1. Population of the World and regions, 2017, 2030, 2050 and 2100, according to the medium-variant projection

<table>
<thead>
<tr>
<th>Region</th>
<th>2017</th>
<th>2030</th>
<th>2050</th>
<th>2100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>1.256</td>
<td>1.704</td>
<td>2.528</td>
<td>4.468</td>
</tr>
<tr>
<td>Asia</td>
<td>4.504</td>
<td>4.947</td>
<td>5.257</td>
<td>4.780</td>
</tr>
<tr>
<td>Europe</td>
<td>742</td>
<td>739</td>
<td>716</td>
<td>653</td>
</tr>
<tr>
<td>Latin America and the Caribbean</td>
<td>646</td>
<td>718</td>
<td>780</td>
<td>712</td>
</tr>
<tr>
<td>Northern America</td>
<td>361</td>
<td>395</td>
<td>435</td>
<td>499</td>
</tr>
<tr>
<td>Oceania</td>
<td>41</td>
<td>48</td>
<td>57</td>
<td>72</td>
</tr>
</tbody>
</table>

US Manufacturing
Manufacturing Supply Chains are Global

Boeing 787

A major case study in complex innovative product development and manufacturing

<table>
<thead>
<tr>
<th>Component Type</th>
<th>Manufacturer</th>
<th>Component Name</th>
<th>Description</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Systems Processor</td>
<td>Qualcomm</td>
<td>Snapdragon 855</td>
<td>8-core 2.84GHz, 8GB RAM, 128GB storage</td>
<td>$290.00</td>
</tr>
<tr>
<td>Memory</td>
<td>Samsung</td>
<td>16GB LPDDR4</td>
<td>DDR4 128GB</td>
<td>$160.00</td>
</tr>
<tr>
<td>Storage</td>
<td>Toshiba</td>
<td>128GB</td>
<td>MLC NAND</td>
<td>$90.00</td>
</tr>
<tr>
<td>Optical Unit</td>
<td>Sony</td>
<td>Sensor</td>
<td>CMOS Sensor</td>
<td>$20.00</td>
</tr>
<tr>
<td>Battery</td>
<td>LG</td>
<td>Lithium-ion</td>
<td>10,700mAh</td>
<td>$150.00</td>
</tr>
<tr>
<td>Power Management</td>
<td>Texas Instruments</td>
<td>Controller</td>
<td>PMIC</td>
<td>$120.00</td>
</tr>
<tr>
<td>Audio</td>
<td>Bose</td>
<td>Earphones</td>
<td>Noise-canceling</td>
<td>$250.00</td>
</tr>
<tr>
<td>Screen</td>
<td>LG</td>
<td>Display</td>
<td>AMOLED 6.3&quot;</td>
<td>$200.00</td>
</tr>
</tbody>
</table>

**Total Cost:** $1,150.00
What is Advanced Manufacturing?

“What is Advanced Manufacturing? It involves both new ways to manufacture existing products, and the manufacture of new products emerging from new advanced technologies.”

President’s Council of Advisors on Science and Technology
Report to the President on
Ensuring American Leadership in Advanced Manufacturing
How will (smart) manufacturing landscape change in the coming years?
Key Terms

• Industry 4.0
  • European vision
  • Fourth Industrial revolution

• Smart Manufacturing
  • US based Smart Manufacturing Leadership Coalition (SMLC)

• Cyber-Physical Systems (CPS)

• Internet-of-Things (IOT)
Fig. 1. Four industrial revolutions.
Figure 5: Stages in the Industrie 4.0 development path (source: FIR e. V. at RWTH Aachen University)
The Boston Consulting Group

Companies should approach the race to Industry 4.0 as a series of sprints, but they should manage their program as a marathon.

Implementers have already captured impressive benefits from Industry 4.0. (See the sidebar “Industry 4.0 Drives Tangible Advantages.”) New ways to generate value from Industry 4.0 are still being discovered, and the value will increase as solutions become more mature and widely adopted. Indeed, some of the technologies, such as the following ones, are still at an early stage in terms of maturity or adoption.

- **Simulation.** Simulation technologies, such as digital twin (which enables creating virtual representations of physical objects, processes, and systems), have the potential to reduce commissioning time, facilitate the coding of machines, and improve quality. Companies can use simulation technologies to troubleshoot potential issues on a production line even before putting it in place.

- **Advanced Robots.** Today, the use of advanced robots is mainly limited to collaborative robots, which work in close proximity to humans and are easily programmable. As the technology progresses, robots will be able to apply the output of algorithms and make decisions appropriate for the context. For example, a US technology startup has designed robots that use vision systems and artificial intelligence to analyze the shape and dimensions of a product and apply this information to determine how to pick it up. This is the initial application of a potentially disruptive change.

---

**Nine Technologies Are Reshaping Production**

<table>
<thead>
<tr>
<th>Technology</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced robots</td>
<td>Autonomous, cooperating industrial robots, with integrated sensors and standardized interfaces</td>
</tr>
<tr>
<td>Additive manufacturing</td>
<td>3D printers, used predominantly to make spare parts and prototypes</td>
</tr>
<tr>
<td></td>
<td>Decentralized 3D printing facilities, which reduce transport distances and inventory</td>
</tr>
<tr>
<td>Augmented reality</td>
<td>Digital enhancement, which facilitates maintenance, logistics, and SOPs</td>
</tr>
<tr>
<td></td>
<td>Display devices, such as glasses</td>
</tr>
<tr>
<td>Simulation</td>
<td>Network simulation and optimization, which use real-time data from intelligent systems</td>
</tr>
<tr>
<td>Horizontal and vertical system integration</td>
<td>Data integration within and across companies using a standard data transfer protocol</td>
</tr>
<tr>
<td></td>
<td>A fully integrated value chain (from supplier to customer) and organization structure (from management to shop floor)</td>
</tr>
<tr>
<td>The Industrial Internet of Things</td>
<td>A network of machines and products</td>
</tr>
<tr>
<td></td>
<td>Multidirectional communication among networked objects</td>
</tr>
<tr>
<td>Cloud computing</td>
<td>The management of huge volumes of data in open systems</td>
</tr>
<tr>
<td></td>
<td>Real-time communication for production systems</td>
</tr>
<tr>
<td>Cybersecurity</td>
<td>The management of heightened security risks due to a high level of networking among intelligent machines, products, and systems</td>
</tr>
<tr>
<td>Big data and analytics</td>
<td>The comprehensive evaluation of available data (from CRM, ERP, and SCM systems, for example, as well as from an MES and machines)</td>
</tr>
<tr>
<td></td>
<td>Support for optimized real-time decision making</td>
</tr>
</tbody>
</table>

Source: BCG analysis.

Note: SOP = standard operating procedure. CRM = customer relationship management. ERP = enterprise resource planning. SCM = supply chain management. MES = manufacturing execution system.
Manufacturing Innovation Institutes (NNMI) and Automation

https://www.manufacturingusa.com/institutes
Value Drivers

• Time to market
• Meeting rapid demand changes
• Service and aftersales
• Quality

• Inventory optimization
• Resource optimization
• Asset utilization
• Labor

Source: McKinsey
Potential Benefits Estimates

- Smart factories could add $500 billion to $1.5 trillion to the global economy in five years
- Efficiency to grow annually over the next five years at 7 times the rate of growth since 1990

Source: Capgemini
The Capgemini Consulting Industry 4.0 Framework

Future Manufacturing Business Model

Agile Operating Model
(Decentralized, Modular, Flexible, Boundless)

GROWTH DRIVER

Smart Solutions
Smart Products
Smart Services

Smart Innovation
Extended Innovation
Connected Lifecycle Innovation

Smart Supply Chains
Agile Collaboration Networks
Connected Supply Chain

EFFICIENCY DRIVER

Smart Factory
Decentralized Production Control
Data-driven Operational Excellence

Governance & Processes

Digital Infrastructure
(Powerful, Secure, Reliable, Scalable)

Technology Enabler (Selection)

Mobile
Cloud
Analytics
M2M
Community
3D-Printing
Robotics

Source: Capgemini Consulting
Figure 13 - Assessment of Technology Enablers' importance for realizing the value drivers of Industry 4.0

<table>
<thead>
<tr>
<th>Technology Enabler</th>
<th>Mobile</th>
<th>Cloud</th>
<th>M2M</th>
<th>Advanced Analytics</th>
<th>Community Platforms</th>
<th>3D Printing</th>
<th>Advanced Robotics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart Products</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Smart Services</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Extended Innovation</td>
<td>○</td>
<td>●</td>
<td>●</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Connected Lifecycle Innovation</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Agile Collaboration Networks</td>
<td>○</td>
<td>●</td>
<td>●</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Connected Supply Chain</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Decentralized Production Control</td>
<td>○</td>
<td>○</td>
<td>●</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Data-driven Operational Excellence</td>
<td>○</td>
<td>●</td>
<td>●</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

Technology Enabler relevancy: Technology Enabler is of little importance for realizing this value driver ○ ○ ○ Technology Enabler is crucial for realizing this value driver ● ● ●

Source: Capgemini Consulting
Internet of Things in Manufacturing

**MANUFACTURING PLANT**
- Monitor production flow in near-real time to eliminate waste and unnecessary work in process inventory.
- Implement condition-based maintenance alerts to eliminate machine downtime and increase throughput.
- Aggregate product data, customer sentiment, and other third-party syndicated data to identify and correct quality issues.

**GLOBAL FACILITY INSIGHT**
- Manage equipment remotely, using temperature limits and other settings to conserve energy and reduce costs.

**CUSTOMER SITE**
- Transmits operational information to the partner (e.g., OEM) and to field service engineers for remote process automation and optimization.
- Provide cross-channel visibility into inventories to optimize supply and reduce shared costs in the value chain.

**GLOBAL OPERATIONS**
- Management: I can see my production line status and recommend adjustments to better manage operational cost.
- R&D: I gain insight into usage patterns from multiple customers and track equipment deterioration, enabling me to reengineer products for better performance.
- Field Service: I know when to deploy the right resources for predictive maintenance to minimize equipment failures and reduce service cost.

Source: Microsoft
IoT Applications

• The application of IoT is projected to generate $1.2 to $3.7 trillion of value globally by 2025, in four primary forms:
  ▪ operational efficiency;
  ▪ predictive and preventative maintenance;
  ▪ supply chain management;
  ▪ inventories and logistics.

• Factory floor efficiency will have the largest impact
  • Increasing productivity by as much as 25 percent.

• IoT + data analytics + machine learning

Source: McKinsey
Smart Products

- Aware
- Connected
- Intelligent
- Responsive
Smart and Remote Services

• Data collection from installed base using CPS and IoT
• Data analytics, machine learning
• Predictive maintenance
• Service delivery efficiency
Thousands of sensors in each Rolls-Royce engine track everything from fuel flow, pressure and temperature to the aircraft’s altitude, speed and the air temperature.

Data instantly fed back to Rolls-Royce operational centers.

Civil aircraft availability center continuously monitoring data from 4,500 in-service engines.

Providing customers with valuable aftermarket services, e.g., showing airlines how to optimize their routes.
Connected Supply Chains

Major improvements in operational efficiencies as intelligent devices connect machines on all the factory floors across a supply chain.

“The idea is that, through digitalisation, our global value chains will be more transparent. In the long term, we want to move away from central steering towards the self-steering of objects in the supply chain.” Oliver Zipse, BMW
Predictive Maintenance

• Using sensors to monitor machinery in real-time, thus “transforming the maintenance model from one of repair and replace to predict and prevent.”

• Example: Ford placed IoT sensors on production equipment:
  • Downstream machines can detect if work pieces from an upstream machine deviate from specifications
  • Possible problems in upstream machines that can be identified and fixed.

• Example: Toyota reduces the burden of recalls by
  • Knowing exactly which machine produced each component of each vehicle
  • Enabling it to track and isolate the problems much more rapidly.

Source: ITIF
Andrew Ng on AI in Manufacturing

“AI technology is well suited to addressing the challenges facing manufacturing, such as variable quality and yield, inflexible production line design, inability to manage capacity, and rising production costs. AI can help address these issues, and improve quality control ... shorten design cycles, remove supply-chain bottlenecks, reduce materials and energy waste, and improve production yields.”
Manufacturing and SMEs

• More than 230,000 SME manufacturers
• More than 98% of manufacturing companies
• Hollings Manufacturing Extension Partnerships focus on SMEs
  • National network in all 50 states, 600 field offices, ...
  • Technology Acceleration, Supplier Development, Sustainability, Workforce, and Continuous Improvement
• 2017 Sikich Report survey of 250 small manufacturers
  • 78% little R&D
  • 77% no plan to implement IoT technologies

![Figure 9 – Share by Size Cohort of Respondents Who Have Engaged in Automation Investment During the Past 5 Years and Plan to Do So During the Next 3 Years](source(s): MAPI Foundation)
Smart Manufacturing and SMEs

• Wide variations in adoption of Industry 4.0 technologies based on:
  • Production and volume mix
  • Production strategy
  • Supply chain technology adoption
  • Input costs – labor, energy, materials
  • Regulations

• Possible recommendations:
  • Strategic analysis of Industry 4.0 from business and technology perspectives
  • Focus on value added, cost reduction, quality improvement, growth
  • Prioritization of technology investments and development
  • Integration between IT and OT
  • Workforce development and skills gap
  • Cybersecurity
UC Irvine is a Leader for the Future of Manufacturing

• Member of two Manufacturing Innovation Institutes:
  
  • Clean Energy Smart Manufacturing Innovation Institute (CSEMII)
  
  • Reducing EMbodied-Energy And Decreasing Emissions (REMADE) Institute
  
• Institute for Design and Manufacturing Innovation (IDMI)
Thank you!

Comments/ideas/questions?

pramod.khargonekar@uci.edu