Overview

- **What is the 'manufacturing system'?**
  - Differentiation between product development and manufacturing

- **History Manufacturing Philosophies**
  - Craft Production
  - Mass Production
  - Lean Production
  - ??

- **Complexity and Systems Perspective in the Manufacturing World**
  - Efficacy and Efficiency
  - Flexibility
  - Adaptability / Learning
  - Holistic View

- **References**
  - Manufacturing at MIT
  - Literature
Product Development and Manufacturing: Intersecting Waterfall Model

**Process Waterfall**
- Enterprise need resources
  - Modeling
  - Engineering
  - Pilot Plant
  - Build
  - Certify

**Product Waterfall**
- Client need & resources
  - Conception & model building
  - Interface description
  - Engineering
  - MANUFACTURING
  - Certification
  - Reconfiguration
  - Operation & diagnosis
  - Evaluation & Adaptation
  - Adaptation
  - Shutdown

adapted from Maier & Rechtin, 2000

History of Manufacturing Philosophies (I): Craft Production

- **Craftsman's Production**
  - Characteristics
    - Highly skilled work force
    - Decentralized organizations
    - General-purpose machines
    - Very low production Volumes
  - Advantages
    - Very flexible
    - Economics focused on variable cost; low level of specific investment
  - Disadvantages
    - High total unit cost

- **Relation to Complexity**
  - Capability limits constrain the growth of the system
  - System is incentive based (agents maximize utility)
  - Product price justifies transaction costs
History of Manufacturing Philosophies (II): Mass Production

- **Characteristics:**
  - Technology
    - *Product has to have a long live (system needs stable environment)*
    - *Interchangeable Parts (Same gauging system, Prehardend Metals, etc.)*
    - *Very short "Cycle Times", Single-purpose Tools*
  - Work force
    - *Only unskilled workers required*
  - Organization
    - Move to higher levels of vertical integration (e.g. Rouge Complex)
    - Vertical Integration necessary to fund complex technologies (Chandler)

- **Advantages**
  - Delivers much higher productivity than craft production as long as product variety is low
  - Only unskilled labor required

- **Disadvantages**
  - High fixed cost (large investments)
  - Inflexible
  - Only unskilled labor required (⇒ inflexibility increases over time)

- **Relation to Complexity**
  - Manufacturing system "grow" more and more complex over time
    (Example: Pratt and Whitney Grinding Machine)
  - Increasing specialization in disciplines makes it harder to see the 'big picture,' i.e. the system
  - Increasing system complexity made optimization disciplines simultaneously more important and increasingly difficult
    - *Operations Research*
    - *Operations Management*
    - ..
History of Manufacturing Philosophies (III): Lean Production

- **Characteristics:**
  - Historical specifics in post-WWII Japan: small home market, strong labor positions, little capital available, strong global competition
  - in essence: Toyota Production System
  - Technology
    - Simple, error-proven
    - Avoid unnecessary complexity (= understand your process)
  - Work force
    - Skilled workers required
    - Life-long job commitment, seniority pays
  - Organization
    - Everyone in the production line is both a customer and a supplier (ref. A. Smith)
    - Decision delegation to lower levels in the hierarchy: workers can (and are expected to) stop the line when they detect an error
    - System in place that quickly traces every problem, once discovered, to its ultimate cause (Five Whys)
    - Manufacturing, supply network, and dealership become one system;
    - that makes smoothing possible (fragile system)

- **Advantages**
  - Delivering much higher total productivity than mass production due to waste (muda) elimination
  - Skilled labor required
  - Ties in customer and supplier into the value chain

- **Disadvantages**
  - If pushed to extreme efficiency, system is fragile
  - ..?

- **Applications beyond the automotive industry**
  - Aerospace (Lean Aerospace Initiative at MIT)
    - Aero/Astro has historically been in the world of military and long-term development, i.e. the focus was primarily on technical performance
    - After the shift of geopolitical situation in the early 1990s, the demand profile on these large-scale and complex systems has changed by increasing the value of time and cost
    - **LAI: Better, Faster, Cheaper instead Faster, Higher, Farther** (Murman et al. 2000)
  - Appliances, Machinery, etc.
Complexity and Manufacturing today

- In the past, technology-stable environments that were created for large scale military projects facilitated the growth of complex systems with increasing complexity (see P&W)

- Economics vary for different processes, i.e. they have their own logic; Depending on the level of analysis, the answer can be completely different
  - Holistic approach can change the economic dynamics

  - Different level of analysis:
    - **Process Improvement**
    - **Operations Management Development**
    - **Factory Flow Redesign**
    - **Lean Infrastructure**

- Lean Production = Complex Adaptive System?
  - Despite being fragile, does it dampen the volatility (bullwhip-effect)?
  - Perfection = Flexibility?
  - Flow = Dynamic?
  - Pull = Adaptation (short term)?
  - Learning = Adaptation (long term)?
  - ..

Future Paths?

- In volatile and fast changing markets, focus may shift from 'perfect efficiency' for one specific environment to survival in many different ones

  - Stochasthic nature and behavior of environment
  - Lean Production systems are fragile by nature (operate on extreme end of operation)
  - Flexibility becomes a value in itself (not equals waste)

- Agile Manufacturing?
  - at marketing level: agile competition is characterized by customer-enriching, individualized combinations of products and services
  - at production level: agile competition is characterized by the ability to manufacture goods and to produce services to customer order in arbitrary lot sizes

- Impact of increasing importance of software technology
  - Spiral model (more prototyping than production?)
  - Software becomes core and hardware is modeled around?

- Relevance of manufacturing?
  - Core competence? (Car vs. Electronics)
  - Systems View: Role and Level of Importance of Manufacturing within the Value Chain (Strategic Decision)
References (I)

- **Manufacturing at MIT**
  - Laboratory for Manufacturing and Productivity
    - investigates how various performance improvement strategies (SPC, TQM, JIT, etc.) fit together
  - Production System Design Laboratory - Prof. Cochran-(http://psd.mit.edu/)
    - PSD is taking a holistic approach at designing manufacturing systems according to the principles of Lean Production
  - Center for Innovation in Product Development (CIPD) - (http://web.mit.edu/afs/athena.mit.edu/org/c/cipd/)
    - Research Projects (selected):
      - *Managing Risk and Managing Knowledge in Product and Process Development: Designing and Implementing Complex Product and Production Technologies*
      - *Product Development Across Firm Boundaries: Problems of Cooperation and Coordination in Large Complex Systems*
  - Lean Aircraft Initiative, Head: Prof. Earl Murman (LAI) (http://lean.mit.edu/);
    - five key themes for research in Phase III: (a) measuring value to the enterprise; (b) time; (c) organizations and people; (d) knowledge and information infrastructure; and (e) government as a lean customer & operator
    - Factory Operations Focus Team Project, selected projects:
      - *Design and Management of Complex Manufacturing Systems*
      - *Lean Assembly System Design for the Lean Aircraft Initiative*
      - *Production Control in Factories and Supply Chains*
References (II)


- Womack, James P., Daniel T. Jones, and Daniel Roos, 1990; The machine that changed the world; HarperPerennial, New York