Appendix 4

p.13, *The Missing Links* by Caroline Mondon (Industrial Press, 2016)

www.themissinglinks.info

A short history of flow – From Venice to Toyota

Common themes in supply chain and operations management can be traced back far in history.

- Work flows to specialized workers rather than workers moving to the work.
- Pre-fabrication and managed storage of standardized components or materials.
- Elimination of activities that increase stock and lead times without adding value.
- Mastery of process for more uniform and reliable (quality) output.
- Pull principles synchronize demand with upstream supply activities.

The following paragraphs highlight some key developments and events in the history of flow.

The Venetian Arsenal (16th Century)

- Established in 1104, the shipyard built the war and merchant ships for the Republic of Venice.
- Largest industrial complex in Europe before the Industrial Revolution (about 45 hectares), including a forest on the mainland for wood supply.
- Hundreds of galleys were built per year with a standardized design and standardized components produced in dedicated areas of the Arsenal (munitions, rope, rigging, etc.).
- The completed hull "flowed" along a narrow channel past the following assembly points to complete the ship in just a day.

Standardization and Interchangeable Parts in the late 18th Century

- French General de Gribeauval (1715-1789) promoted standardized artillery weapons.
- Standardized components, tools and manufacturing processes improved uniform "performance" of arms, allowed using standardized ammunition and producing spare parts for old equipment.
- Interchangeable parts are specified and produced in such a way that they are, for practical purposes, identical. Production, assembly, and repair are easier, faster and require less skill.
- Interchangeability enabled the development of the assembly line.
- In the early 19th century the English Navy needed 100,000 pulley blocks a year. Power-driven, purpose-built, highly accurate machinery made markings and indentations on the blocks to ensure alignment throughout the process. Result: annual production of 130,000 blocks by 1808.

Adam Smith and Specialization and Division of Labor in a "Complex Adaptive System"

- Scottish economist and philosopher Smith (1723-1790) observed how guilds of weavers allowed members to use specialized services for sales, marketing, distribution and manufacturing for mutual benefit: higher output, economies of scale and faster processes.
- Specialization and transactions have become the cornerstone of all business relationships.
- Smith described economics and trade as action and feedback processes with multiple causes and effects rather than a linear model of nationally defined and controlled inflows of gold and raw materials and outflow of goods. Today, we would call this a "complex adaptive system".

Frederick Winslow Taylor and Scientific Management During Industrialization

- Industrialization called for more and more coordination to synchronize work and logistics activities, while growing demand for industrially produced goods required higher productivity.
- Taylor (1856-1915) applied engineering efficiency principles to labor and parts flow in order to find the objectively cheapest, quickest, and most accurate way for each manufacturing process.
- Four principles of scientific management: (1) Develop standardized work methods (based on scientific study of the tasks); (2) Select, actively train, and develop each employee to perform the process following the standard; (3) Instruct and supervise workers in performing their tasks; (4) Divide work between managers (planning and coordination) and workers (carrying out tasks).

Henry Ford and the Moving Assembly Line

- In 1913, Ford introduced the moving assembly line at the Highland Park factory for the Model T.
- Interchangeability, standard work, simplified operations, and moving conveyance (gravity slides in the beginning) led to flow production.
- All resources (people, machines, equipment, tools and products) were arranged to allow a continuous flow of production. Typical machine output was determined and used for scheduling purposes. With the assembly line, the line controlled the speed and not the employees.
- The system could not provide variety. The Model T came in one color and specification; practically every machine worked on a single part number, there were essentially no changeovers.

Supermarkets Revolutionize Retail Flows and Shopping Behaviors

- The first true supermarket in the US opened on August 4, 1930 in New York City.
- Basic idea: self-service, uniform stores, selling large volumes of food at discount prices and adding a parking lot. The supermarket profoundly changed the flow pattern in retail.

W. Edwards Deming Brings Quality to Japan in the 1950s

- In 1950, Deming taught statistical process control to Japanese scientists and engineers as part of an effort to rebuild Japanese industry after World War II.
- These techniques allowed to improve quality (at the source) and productivity. Better quality and lower cost created significant new international demand for Japanese products.

The Toyota Production System (TPS): Breakthrough for Flow

Sakichi Toyoda develops Jidoka and the "Five Whys" at the Toyoda Spinning and Weaving Company to mitigate product defects and associated wasteful work practices:

- Jidoka ("automation with a human touch") allows to detect abnormalities early, then easily stop the machine or process, and immediately fix the issue.
- The "Five Whys" help investigate the root cause of the issue: an iterative interrogative technique is used to explore the cause-and-effect relationships underlying a particular problem.

Kiichiro Toyoda (Sakichi's son) and Taiichi Ohno break ground for the TPS:

- In the 1930s, Japan's protectionist policies made foreign car imports and even knockdown assembly impossible. Domestic companies, mainly Toyota Motor Company and Nissan, grew from 3% to market dominance, despite poor quality, low productivity and a lack of funds.
- After the Second World War, the Japanese car industry was in stagnation and Toyota lost money.
- Toyoda and Ohno visited the USA and Ford's plant to study the assembly line concept. They added innovations to provide process continuity and a varied product offering while reducing waste.
- Ohno was highly inspired by the supermarket system to develop the Kanban concept. A work-center that needs parts takes the needed quantity of a part from the inventory storage point. The exact withdrawn amount is restocked on the shelf by the serving work-center.
- Ohno also used Deming's methods to incorporate quality at each step of the process from design to aftersales services. He combined this with Kiichiro Toyoda's just-in-time concept and principle of Kaizen. Ohno developed the concept of the seven wastes (*Muda*) and is considered the true architect of the TPS (a major precursor of "lean manufacturing").
- The TPS is an integrated socio-technical system that organizes manufacturing and logistics for Toyota, including supplier and customer interaction. It shifted the focus from individual machines and their utilization to the flow of the product through the entire process: Machine capacity is aligned with the actual volume needed; self-monitoring machines ensure quality (Deming's mistake-proofing); machines are lined-up in process sequence (often in U-shaped cells); quick setups ("SMED") allow making small volumes of many part numbers; each process step notifies the previous step of its current needs for material (Kanban); parts move in pull flow from step to step with no work-in-process in between (one piece at a time or a small batch, one piece flow).
- Result: low cost, high variety, high quality, rapid throughput times to respond to changing customer desires together with a much simpler and more accurate information management.

For more information please contact Christoph LENHARTZ christoph.lenhartz@catena-strategies.com