Chapter 2
Assembly Systems

Introduction

An assembly line is a manufacturing process where the bill-of-material parts and components are attached one-by-one to a unit in a sequential way by a series of workers to create a finished good product. All of the tasks to fully produce the product are identified and as much as possible the task times are evenly assigned to the workers, whereupon the units are produced one after the other. This method of production has proven to be much more efficient than having a series of craftsmen entirely producing each finished good product one at a time. Adam Smith in the 1776 classic "The Wealth of Nations," introduced the term "division of labor". This involves the partition of a complex production process into one or a few simpler tasks, with each task assigned to a different worker. Smith gives an analysis of a pin factory where the time and physical movement of the workers were reduced throughout.

This chapter is partitioned into two sections: History of Assembly Lines and Type of Assembly Lines. The history begins in 200 BC in China where 8,000 sculptures known as the Terracotta Army were produced in an assembly type manner. In the sixteenth century, the Venetian Arsenal built standardized parts to equip its ships (galleys) using assembly methods. Oliver Evans of Delaware, in 1785, applied assembly methods in a flour mill; Eli Whitney, in 1797, used assembly lines to build muskets for the U.S. government. Assembly systems were in use in England at the Portsmouth Block Mill in 1800, and at the Bridgewater Foundry in 1836. Assembly systems were also in use in the USA during the nineteenth century, particularly in the armories; and in 1867, in the meatpacking industry in Chicago. In 1901, Ransom Olds is credited as the first to apply assembly methods to automobiles increasing his output from 1 to 5 units a day. Henry Ford designed and built the first successful automotive assembly line. His factories produced hundreds of Model T Fords each day. Ford's innovative methods paved the way for the use of assembly lines all over the world. The chapter also describes the various types of assembly lines: single model assembly,

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batch assembly, mixed model assembly for make-to-stock, mixed model assembly for make-to-order, postponement assembly, one station assembly, disassembly, and robotic assembly.

History of Assembly Lines

Terracotta Army One of the earliest discoveries of an assembly line took place in China in 200 BC. In 1974, a collection of sculptures depicting the armies of the first emperor of China was discovered by a group of farmers. The discovery included 8,000 figures of warriors and chariots that were buried with the emperor in 210 BC. Historians state that the army figures were manufactured in workshops by laborers and craftsmen at the direction of the government. The parts of the figures (head, arms, legs, and torsos) were created separately and then assembled. Final touches were added to give different facial looks, and each workshop inscribed its name to the units they produced to ensure quality control. The process was like an assembly line production, where the individual parts were first formed, then fired, and later assembled.

Venetian Arsenal In the sixteenth century, the Venetian Arsenal employed 16,000 people who manufactured standardized parts of ships (sails, oars, wheel carriages, guns, rigs, ropes, munitions, etc.), in an assembly line manner. These parts were used to fully equip newly built galleys that were produced on a basis of almost one a day. A galley is a type of ship that is propelled by many rowers on both sides and was used for warfare, trade, and piracy.

Oliver Evans In 1785, Oliver Evans, in the state of Delaware, built the first automatic flour mill. The mill used a leather belt bucket elevator, screw conveyors, canvas belt conveyors, and other mechanical devices to completely automate the process of making flour. The innovation spread to other mills and breweries.

Eli Whitney In 1797, Eli Whitney used an assembly line to mass-produce muskets for the U.S. government. All the parts of the musket were produced in advance and with the same engineering tolerance so that each could be inserted onto any musket. In this way, the parts and components were common and made assembly possible. The common parts also were used subsequently to replace a musket part that had been damaged. Prior to Whitney, each musket was produced entirely by an individual craftsman. The parts and components were crafted to fit the individual musket. Because of this, the parts were not common and interchangeable from musket to musket.

A few years after in 1797, in firearm-manufacture, Whitney and other manufacturers began using machine tools and jigs to produce the parts and components. The equipment's ability to produce standard interchangeable parts with specified tolerance was used to replace the skill of the workers and allowed the hiring of less-skilled workers.

Portsmouth Block Mills In 1800, Samuel Boulton and James Watt, working at the Portsmouth Block Mills, in England, developed woodworking machinery for up-and-down saws and for circular saws. These were housed in a three-story woodworking building where the heavy products were transferred by flat belts running on pulleys. The machinery was used to cut timber into a variety of smaller parts (components for tables, benches, pumps, etc.), that were used in shipbuilding. Previously, these items were cut by hand. In 1802, The British Navy required 100,000 pulley blocks of various sizes, and was unsatisfied with the production of hand-made blocks. At Portsmouth Block Mills, Mac Isambard Bruner with Henry Maudslay and others designed 22 types of machine tools to make the parts for the blocks used by the Royal Navy, and successfully fulfilled the Navy's need. They are credited with one of the first linear and continuous assembly processing system.

Bridgewater Foundry James Nasmyth and Holbrook Faskell founded the Bridgewater Foundry in 1836 in England. Nasmyth designed and manufactured a large set of standardized machine tools (steam hammer, planers, shapers, pile drivers, hydraulic press, etc.), mainly for locomotive application. The firm is credited with using material handling methods in production that paved the evolution of the assembly line. Nasmyth arranged the factory in a line with a railway carrying the work from one building to another. Cranes were used to lift the heavy items. The production passed in a sequential way from erection of framework to final assembly.

American System During the nineteenth century, a wave of new manufacturing methods started in America allowing an upsurge in labor efficiency, particularly in the armories where products were produced for the U.S. government. This included increased use of interchangeable parts and mechanization of tools, fixtures, and jigs in the production process. The system applied specialized machinery instead of hand tools. This advance in manufacture is also referred as the armory practice since it was implemented mainly in the Federal armories.

The American system fostered continual innovations in machines, tools, fixtures, jigs, and part standards that could be carried out efficiently by semi-skilled workers. The workers were able to run the specialized machines that produced identical interchangeable parts that were made to the specified standards set by the engineers. All of this in minimum time compared to the individual craftsmen way.

In this era, the separation of manufacture of parts and components from assembly became possible. One set of workers could produce the parts and components, and in a separate facility, another set of workers could perform all of the assembly. Soon, this system became common in all the industries in the USA and around the world.

Meatpacking In 1867 in Chicago, the meatpacking industry created one of the first industrial assembly lines in the United States. The workers stood at their assigned stations as a pulley system brought the meat to their station allowing the worker to complete the task assigned to the station. This essentially is a disassembly operation.

Pre 1900 Prior to 1900, most manufactured products continued to come from the craftsmen who worked individually. The different parts were crafted one-by-one with files, knives, and other tools in a trial and error manner until they fit together. Then, the parts were assembled to produce the finished good item. In England and in New England, the manufacturing way slowly was changing. The advent of jigs, fixtures, machine tools, lathes, and planers paved the way to interchangeable parts and assembly applications. Different forms of assembly lines started to pop up in a variety of industries (textiles, clocks, horse drawn vehicles, railroad cars, sewing machines, and bicycles).

Ransom Olds In 1901, Ransom Olds developed the first automotive assembly line for the Olds Motor Vehicle plant in Detroit, Michigan, where the vehicle was the Oldsmobile Curved Dash. The new approach to putting together automobiles enabled Olds to increase the annual factory output from 425 cars in 1901 to 2500 in 1902. Ford improved Olds idea by installing conveyor belts. Some credit Olds as “the father of automotive assembly line”, and Ford as “the father of automotive mass production.” Although history cites Olds as the first user of automobile assembly lines, Henry Ford is recognized as the initial pioneer since he took the concept and perfected it for all generations.

Henry Ford Henry Ford’s early career was a Chief Engineer in Thomas Edison’s electrical lighting plant in Detroit, Michigan. His interest, however, was internal combustion engines, and had a desire to develop a vehicle that would be driven by one. In 1902, after Ford left Edison, he founded the Ford Motor Company. He started to build vehicles of various models, but was hampered because he had little cash available. He began to offer dealer franchises that required the dealers to pay for the vehicles upon delivery to them instead of after they were sold. With this added infusion of funds, he had capital to advance his manufacturing facility and continue researching to improve the model cars. He produced various models, including some for luxury and others for racing.

His vision was to build an auto that the common workingman could afford. In 1908, he introduced the Model T that would soon become the auto he was seeking. Up to that time, the vehicles were custom-built one at a time in small quantities. In 1909, he started a facility to apply assembly methods. Little by little, improvements took place. He installed moving belts so that the workers could remain at one location and do their one task efficiently and in minimum time, rather than assigned a variety of tasks. With the efficiency in production, the line soon was producing 1,000 vehicles per day. Ford was then able to lower the cost of the vehicle to $290, and this was in the range of the common man. By 1915, he produced almost half of the world’s automobiles, and by 1923, the production rose to 1,800,000 per year. With all the efficiency in production, the worker’s skill level was deteriorating. The assigned task per worker was not challenging and became boring. Some workers left the plant for other jobs more stimulating.

Ford recognized the problem and proved innovative in finance as well. In 1914, he offered his workers a wage of $5.00 per day; that was well ahead of the typical workers wage. Doing this, he gained many new workers. This high wage also allowed the workers to afford the vehicles they were producing; and as a result, his sales went up tremendously as a result. By 1927, over 15,000,000 Model T’s were sold. With the proliferation in vehicles, the state and city governments required new roads and networks where vehicles could travel. This also included the need for a series of petrol stations and traffic controls. A whole new industry of tourism became fashionable. People could now visit places that previously were out of reach.

Type of Assembly Systems

Single Model Assembly A single model assembly is where the line is dedicated to one model. For example, a washing machine manufacturer produces three models (A, B, and C). The models are assigned to individual lines, and model A is placed on a line that runs on one shift per day of 450 min. Each unit of the model is the same with no variations. The schedule over the planning horizon calls for 200 units per day. Because A is the only model on the line, the line is called a single model line. A goal of the management is to assign the work elements associated with the model to the station operators as evenly as possible in way where the workload can produce the 200 units over the shift.

Batch Assembly Consider again the manufacturer with three modes (A, B, and C) and one assembly line. In batch assembly, the models are assigned to the line in pre-assigned sizes, where model A is run until its inventory is at a specified level, and in the same way, then model B is run and finally model C. The cycle continues where the models are assembled in batch sizes that satisfy the warehouse inventory levels allowing sufficient stock to meet the oncoming customer demands. With each change in model on the line, the station operator's workload needs to be changed accordingly. Essentially, each model is run as a single model line.

Mixed Model Assembly for Make-to-Stock Mixed model assembly occurs when more than one model of a product is assigned to the same assembly line at the same time. An example is the washing machine manufacturer with models A, B, and C, where all three models are assigned to a line. Over the planning horizon, the daily shift schedule calls for 100 units of model A, 70 of B, and 30 of C. The models are different, but the units of each model have no variation. The two main tasks for this type of line are line balancing and sequencing. Line balancing is the process of assigning the work elements to the station operations in a way where each operator's workload is as even over the shift as possible. Sequencing is the arrangement of sending the units down the line in a way where the workflow minimizes lapses of idleness and congestion over the shift and at all of the stations.

Mixed Model Assembly for Make-to-Order Mixed model assembly for a make-to-order manufacturer occurs when the manufacturer's product is offered with a series of features and options. Each customer order specifies the option for each feature of the product. This way, every customer order is unique and often no two orders are the same. The customer order is called a job. Typical of this type of manufacture is truck assembly, where the customers have individual needs on their vehicles. The assembly process first requires the task of assigning the workload to the station operators where the shift workload is as even as possible. This is difficult, since each day, the units coming down the line are different. Projection of features and options over the planning horizon are needed in assigning the workload to the individual stations. The management next has to determine which jobs to assign for assembly in a shift. Each job has a due date and a bill-of-material that is unique to the job. When all the parts and components for the job are available and the due date is proper, the job is scheduled for assembly on an upcoming shift. The management must then determine a sequence of the jobs for each shift that allows a smooth flow of the workload with the least amount of idle time and congestion time among all of the stations on the line.

Postponement Assembly Postponement assembly is a supply chain strategy that could apply to manufacturers that offer products that have a series of features and options, where the customer orders are for a particular combination of the options. Postponement is where the assembly line partially completes the products so that they can be fully completed at the later time prior to delivery to the customer. An application are college pennants that are produced and stored without any color. When the customer orders come in, the name and colors are inserted accordingly. Another situation is farm tractor assembly where the units are produced and stored in a stripped down manner awaiting customer orders with the specific features. As each customer order arrives, the features are inserted onto one of the stripped down tractors.

One Station Assembly One station assembly happens when all the assembly work to complete a unit is assigned to one person in one station. This could be an engine assembly in a small shop that builds specialty engines. Another example is a shoe manufacturer that assigns 12 pair of shoes from a particular style and a combination of sizes to a worker. At the outset, all of the material to complete the 12 pair is delivered to the worker's station. The worker may spend one or more days on completing the assigned pairs.

Disassembly A big effort in environmental control is the recovery systems associated with disassembly and recycling. Efforts by consumer groups and government are encouraging corporations to design and produce environmentally harmless products. This same effort encourages the firms to reengineer their products so when they are to be replaced or discarded, the parts and components can be readily removed for possible reuse in new items. This is taking place particularly in the following type of products computers, printers, copy machines, rifles, pistols, iphones, clocks, watches, lawnmowers, snow blowers, and irons.

Disassembly is also important in the reuser of the mechanisms of electromotive, trucks, buses, automobiles, agriculture, and construction equipment; they include engines, transmissions, drive shafts, clutch, drive axle, driveline, steering gears, and pumps. At some point, these major components of the vehicles are of no more use and are removed and replaced. Instead of scrapping the units, many are purchased by various remanufacturing corporations where they are called cores; and are stored in a warehouse facility. A core is essentially a main component that is capable of remanufacture and worthy for reuse. Note, for an engine, the main core is the engine and the component cores are the components taken out of the engine. When customer demands arise, the cores are taken from the warehouse, disassembled by removing the inside components. The components are cleaned and inspected for future use, repaired if needed, and scrapped if not acceptable. When all the components are available, either from the disassembled unit or from new purchased components, the main core is assembled, tested, and put on sale with a full warranty.

Robotic Assembly A common problem facing assembly line workers is the continual repetitive work that causes physical and mental fatigue. The workers require various breaks during the day for eating, relaxing, and bodily needs. In contrast, robots work for long hours and require no breaks. The robots are capable of performing assembly tasks ranging from routine to precise without losing quality. A robot is a device that is programmed to perform a variety of tasks. With various controls, the assembly engineer steers the robot to perform as needed for the specific task that it is assigned.

Manufacturing robots are costly due to expenses in designing, hardware, operating software, installation, and maintenance. But when compared to hiring and maintaining a human worker, the long-term cost could favor a robotic station. Robots do not require wages, benefits, vacations, insurance, severance pay, pensions, or union demands. Any time after installation, the robot can be upgraded and replaced for an advance model without any worker repercussions. To do the same to a human worker may cause the need for severance benefits or the possibility of a lawsuit.

Quality workmanship improves with the installation of robots in place of humans, as long as the robot is running smoothly and the parts and components of installation are without fault. A problem could occur with poor fixtures or parts that slip out of the grippers of the robot. A maintenance operator is assigned to monitor a series of robot stations in the event of a mishap. In general, the robots are very reliable and require minor maintenance.

Balancing of a robotic assembly line is the process of ensuring the work times at each station will allow the flow of units to pass along smoothly with minimum delays. The plant may have a variety of robot types where each has different capabilities and speeds. The best robot for each station has to be assigned depending on the task of the station and the capabilities of the robots. When a new product is planned for assembly, the assigning of robots to the stations may need to be rearranged. Some of the robots may need to be reprogrammed by guiding its arms and pushing a few buttons.

Robotics is in use in a variety of industries (automotive, aerospace, electromotive, medical, consumer goods, electronics, and industrial). Some assembly lines are partially automated and others are fully automated with robots, and the robots within have applications ranging from handling small to large objects. Common applications are welding, testing, serial part marking, labeling, drilling, cutting, spraying, painting, grinding, molding, material removal, material movement, milling, polishing, bonding, and water jet.

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