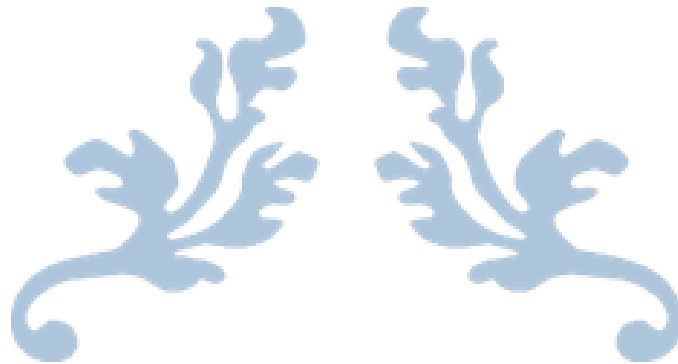




Development and application of manufacturing automation

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The History of manufacturing automation

Rise of the assembly line

Before advanced automation as is known today, products were made in vast numbers to supply the masses, with an aim for a long service life. To produce such large volumes of products, Henry Ford pioneered the famous dedicated moving assembly line in the early 20th century. N. Bhuiyan, A. Baghel, Management Decision (2005). These production lines allowed a vehicle to be assembled in 90 minutes from 12 hours. After this innovation it was not only Ford Motor company to benefit, as consumers could now purchase a vehicle at a significantly lower price.

<https://corporate.ford.com/articles/history/moving-assembly-line> (Viewed 02/04/2023).

Japan's contribution

Post world war and upon defeat, Japan was in a phase of nationwide reconstruction. An industrial rebuild program was initiated, the program relied on superior manufacturing methods different to the rest of the world. Hence, Japan became dominant in industrial automation. Automotive companies like Toyota, Honda and Nissan could output high quality and reliable vehicles.

www.automate.org/editorials/the-history-of-industrial-automation-in-manufacturing (Viewed 02/04/2023).

The computers impact on automation

The advancement of the digital computer in 1946 (ENIAC) allowed a complex control function to be processed, calculations became much quicker than originally allowed. Although, this technology was cumbersome and required large expanses of space to contain the equipment. ENIAC. (2016). Forward to the 1960s, integrated circuits (chips) allowed a reduction of physical size and price. The performance of these chips was largely enhanced compared to their predecessors, alongside these advances, programming methods improved which allowed engineers to become proficient in the use of computer technology <https://www.britannica.com/technology/automation/Modern-developments> (Viewed 02/04/2023).

Control model theory

By the 1950s, engineers found that control systems are non-linear, as most measurements are contaminated with noise, it was also understood that systems were performing unreliably in uncertain environments. There was a need for a new numerical model using mathematical/physical mass energy balance. White-box models are thermal dynamics models, which are based on fundamental laws of physics, thermodynamics, and heat transfer. Generally, this approach can be roughly classified into two types: physics-based models using simulation tools such as physics governing law-based thermal dynamics state-space equation or lumped capacitance model (Salakij et al., 2016).

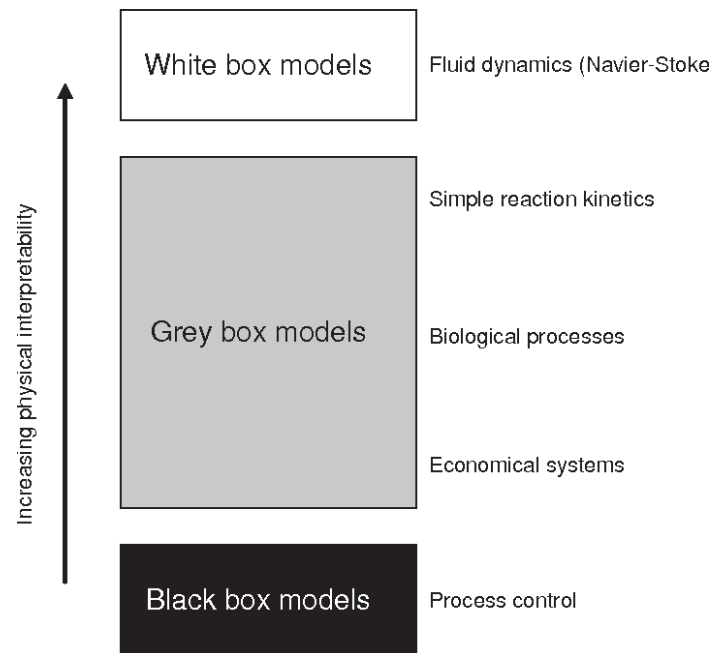


Figure 1.

Lith, Pascal F. van. (2002).

Programmable Logic Controllers

Come the 1960s, the first plc was born termed “Modicon”, which stood for modular digital controller. It was designed to be rugged and basic; this allowed the machine to survive harsh conditions. The controller gained huge interest from engineers who quickly began to tinker and modify their own ideas into the device. Modicon was not the only Team to innovate these PLC’s, siemens, Mitsubishi, General Electric and Schneider all contributed to the development of the PLC (Programmable Logic Controller). As an example, in 1965 Siemens top model could only perform 15 instructions per second compared to 32,000 in 1988. This proved the rapid development of digital computers in line with Moore's law (Hayden, Assante, Conway 2014).

Industrial Robotics

Industrial robots were first installed to unload parts from a die casting plant in 1961. They proved essential for repetitive tasks where an elevated level of consistency is required. They can be considered a product of both numerical control, which provides a programmable, commandable industrial machine and also teleoperator technology, which is often a mechanical arm which manipulates the environment around it. The development such machines can be credited to Americans George C. Devol, an inventor, and Joseph F. Engelberger, a businessperson. The duo went on to promote the advantages of robotics in industry after which they established the first corporation of robotics – Unimation, inc www.britannica.com/technology/automation/Development-of-robotics (Viewed 10/04/2023).



Figure 2.

www.kuka.com/en-ch/industries/solutions-database/2016/07/solution-robotics-hall-10 (Viewed 10/04/2023)

Classifications of automation

Fixed automation

Fixed automation, also known as “hard automation,” has proved to be an especially important system which provides many benefits to a company. There are many configurations possible but once chosen they are fixed into position. After construction of the plant, commands are ingrained into the mechanical movements of gears, cranks, arms, pulleys, and other physical mechanisms. If a change of manufacturing to the product is required, vast changes must be made to accommodate new production techniques. Therefore, this mode of production has a high initial funding but can also produce mass volumes of products. A few examples of fixed Manufacturing lines could be paint and coating processes and packaging lines.

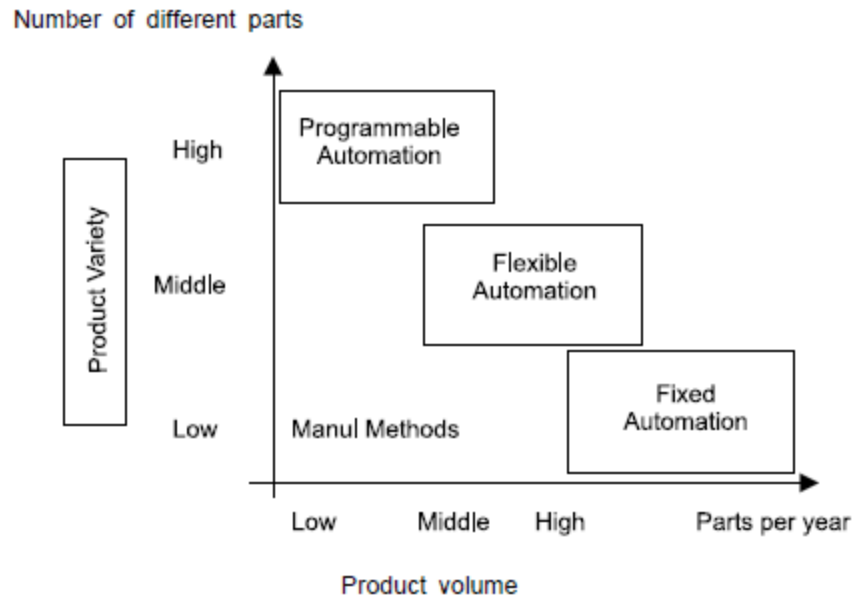


Figure 3. Product volume vs variety

<https://www.wisdomjobs.com/e-university/production-and-operations-management-tutorial-295/types-of-automation-9679.html> (Viewed 10/04/2023)

Programmable automation

A programmable Manufacturing technique provides complete customizability, it encumbers a use of electronic controls to supply common Switch ability, it is often used in “batch” production which allows varying volumes of units to be produced. A drawback to these systems is they require significant reprogramming time in between orders which equates to increased labor costs. Examples include CNC machines and culinary produce.

Industrial robots are playing a vital role in this area, they are continuously being developed to produce batch discrete part goods. As a contrast to fixed systems, they are designed for flexibility in the ease of setting up for an ever-changing product. A quick change of programs and the robot can adapt to various parts and respond to a changing environment. C.A. Rosen, (1977). Many industrial robots (of the first generation) are undertaking simple and repetitive material handling tasks, they are often working in dangerous or human limited environments. Second generation robots incorporate a processor, which allows advanced duties to be performed. These advanced machines utilize many sensors to enhance computer control and allow robot manipulators to exceed human performance in many lines of work.

PLC BLOCK DIAGRAM

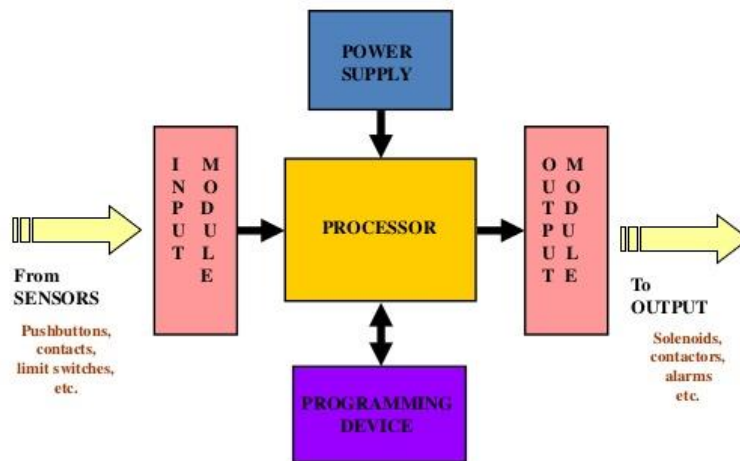


Figure 4. PLC block diagram

<https://www.polytechnichub.com/block-diagram-programmable-logic-controller-plc/> (Viewed 16/04/2023)

For advanced material handling systems to be successful they must fulfill two requirements. Requirement one is the robot must be able to acquire randomly positioned and disordered workpieces, from set locations or moving conveyers and transport them via a preset path to a target. The second requirement is for the robots to place the workpiece or assembly with an orientation with a specified precision. <https://www.britannica.com/technology/automation/Manufacturing-applications-of-automation-and-robotics> (Viewed 16/04/2023)

Flexible automation

A flexible manufacturing system (FMS) is defined as a production unit capable of producing a range of discrete products with a minimum of manual intervention (US Office of Technology Assessment, 1984). An FMS is an integrated, computer-controlled complex of automated material handling devices and numerically controlled (NC) machine tools that can simultaneously process medium-sized volumes of a variety of part types. Globalization demands a new dimension: flexibility in manufacturing (Jaikumar 1986). FMS is considered an extension of programmable automation; a common disadvantage of programmable automation is how long it takes to reprogram and rearrange tooling for a new product. Lost production time equals loss of money, flexible automation ensures the product range is limited so that the change of equipment can be done quickly and autonomously.

Equipment reprogramming in flexible automation takes place offline. This means that programming is done on computer terminals without using the production equipment itself. Therefore, it is not necessary to group identical products into batches. Instead, you can create different product

combinations in succession. This production technology was developed to achieve balanced machine-timed transfer line efficiencies while taking advantage of the flexibility workshops needed to process multiple part types simultaneously (Browne, Dubois, Rathmill, Sethi, Stecke 1984).

With consumer tastes changing rapidly, competitive outcomes are heavily influenced by the degree of manufacturing flexibility that allows companies to quickly adapt to the changing environment. A flexible manufacturing system that can tailor products to different consumer tastes is considered superior to technology that can only produce specific or niche products. If so, we should expect flexible technology to replace inflexible technology. However, Norman and Thisse (1999) argued in earlier work that flexible manufacturing leads to more competitive pricing systems, and that the introduction of such technology may reduce profitability. The degree of economies of scale that would be realized in the production of a single homogenous good if consumers were perfectly stable. Manufacturing techniques in this environment typically involve dedicated mass production systems to produce the desired product. However, in a market where consumer tastes often fluctuate, committing to such a dedicated manufacturing system can be disastrous.

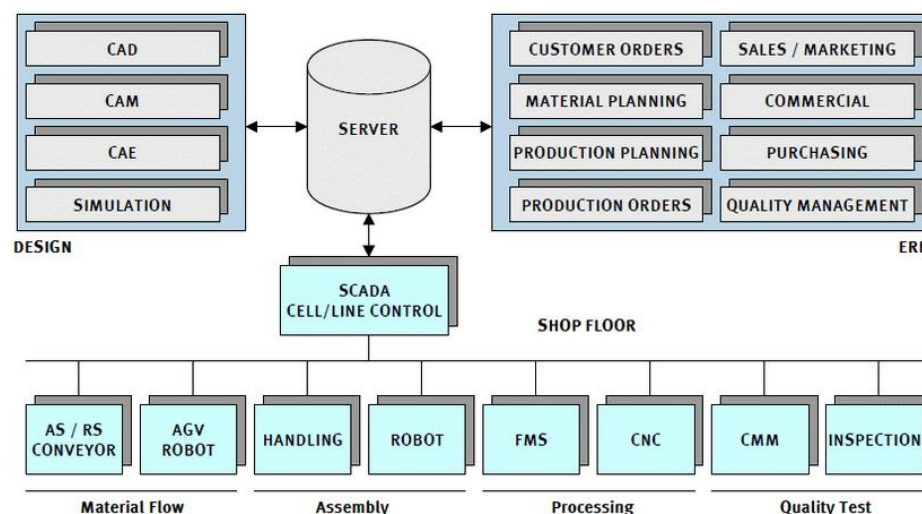


Figure 5. Modular flexible manufacturing system block diagram

www.researchgate.net/figure/Modular-flexible-manufacturing-system-block-diagram_fig1_292520032
(accessed 16/04/2023)

Ford Motor company

A good example of the negative outcome of a commitment to fixed manufacturing is the Ford Motor Company's transition from the Model T to the Model A. Henry Ford's production of the Model T required extensive use of highly specialized technology intended for low-cost, high-volume production. Mass production with proprietary technology increased volume and profits in an era of steady consumer taste but could not keep up with the model changes needed by the eventual shift in public taste that accompanied Chevrolet's entry into the market. The inflexibility of the manufacturing facility, which took over a year to transition from the Model T to the Model A, meant that all Ford's manufacturing plants had to be closed for equipment modifications and redesigns Rae (1984).

Flexible automation within the flat pack industry

In today's industry, unique products require ultimate customization desired by the end user, buyers can virtually simulate the product to their own requirements. This requires a high degree of flexibility in manufacturing. The new sweep of automation by the flat pack industry covers a broad array of robotics for painting, packing and palletizing applications, as well as IRC5 controllers, PickMaster software and advanced vision-guided technologies www.automationmag.com/892-robots-assembles-the-perfect-flat-pack/ (viewed 16/04/2023). This range of flexibility allows manufactures to keep in line with the latest interior design trends. Another reason flexible manufacturing thrives in this industry is the reduction of risk to line workers. Repetitive strain injury (RSI) is a term sometimes used for pain caused by repeated movement of part of the body www.nhs.uk/conditions/repetitive-strain-injury-rsi (viewed 16/04/2023). By replacing the repetitive task with an autonomous bot, the risk of injury is eliminated.

Wood-based panels such as plywood, plywood and fiberboard, especially medium density fiberboard (MDF), are widely used in furniture manufacturing and interior design. (Akbulut and Ayrlmis, 2019) Application of advanced technology such as CNC machines and automation systems is one of the main reasons behind the growth of the furniture industry. In the furniture industry, companies prefer CNC machines for processes such as patterning, milling, drilling, and grooving (Sofuoglu, 2017). The integration of CNC machines with other automation systems allows ultimate flexibility, thus reducing time loss in furniture manufacturing and increasing productivity by a factor of 2.5 (Koc et al., 2017).



Figure 6. CNC mill producing MDF Laminate

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