

ACMA5001

Development and Application of Manufacturing Automation



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1.0 Abstract

The International Society of Automation (2023) define automation as “the creation and application of technology to monitor and control the production and delivery of products and services”.

Manufacturing automation is the use of advanced technology and equipment to increase production output and minimise the use of human labour. Technology such as industrial robots, programmable logic controllers, machine vision systems and sensors are used to efficiently meet increasing product demand.

The following report covers the three main manufacturing automation methods, fixed, programmable and flexible which each have their own advantages and disadvantages depending on production quantity. This report also looks at the history of these methods and how they came to emerge. Having researched the types of manufacturing automation, a solution has been proposed to the implementation of flexible automation in a well-established industry.

2.0 Main Body

2.1 Types of Automation

2.1.1 Fixed Automation

This type of automated manufacturing system refers to equipment that is programmed to serve one purpose. As Captech Automation (2022) explains, unlike programmable automation the manufacturer sets the equipment to perform only one task repeatedly. Also referred to as “hard automation”, systems are often difficult to adapt to suit a variant of products. Commands are often governed by cams, gears, and hard wiring. With high initial investment this type of automation is often used for mass production of singular products (Britannica, 2023).

2.1.2 Programmable Automation

Programmable automation is used when there is a variation of products produced on an assembly line. This automation type is easily re-configurable, Britannica (2023) explains that “programmable automation is a form of automation for producing products in batches”. Upon the introduction or requirement for a new batch, equipment is re-programmed to suit the changeover. This changeover period is however classed as ‘non-productive’ and can often take time to complete and confirm. Rates of production are often found to be lower than that of fixed automation as production lines are designed to be programmable or adaptive depending on product demand, whereas fixed automation is more specialised on one product type which often leads to higher production rates.

2.1.3 Flexible Automation

Lofving, M (2018, p. 177-184) defines Flexible Automation as “rapid configurability of the production system in order to manufacture several different products, achieving a high degree of machine utilisation, reduction of in-process inventory, as well as a decrease in response times to meet the changing customer preferences”. Flexible automation is often described as an extension of programmable automation, having the ability to flexibly change the assembly line to suit a change in customer demand. In many industries this is critical to ensure that sales of the products remain high. Most flexible automation systems utilise robotics that can be programmed to complete numerous tasks depending on product type. With a change in production, these robots can be ‘re-tooled’ and re-located to suit without the need for re-programming which often leads to down-time (WAKE Industrial, 2021).

As Figure 1 shows, Fixed automation manufactures a greater number of parts but with minimal part variation. Flexible automation uses robotics to produce a high number and variety of parts with the systems already set in place to easily accommodate customer change in demand. Programmable Automation can produce a high variety of parts however due to the nature of re-programming; production volume is often sacrificed due to down time.

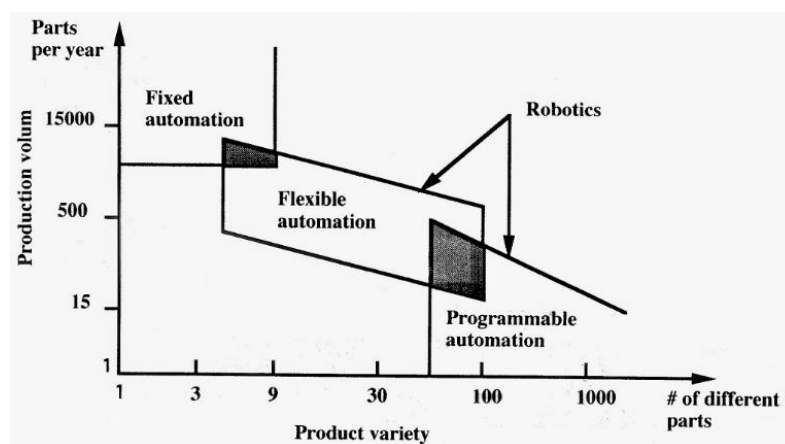


Figure 1 - Volume vs Variety Automation Methods

2.2 Automation in Industry

2.2.1 Industrial use for Fixed Automation

As mentioned, Fixed automation is ideal for high quantity production of the same parts. Fixed automation does not economically allow for equipment changeover, if this is required then a shutdown is often implemented in which engineers manually change tooling. Some examples include the automotive industry, material handling conveyor systems, painting, and coating processes as well as but not limited to chemical manufacturing processes (Fast Radius, 2021).

The automotive industry utilises fixed automation to drive production output and decrease the production cost of the vehicle to sell at a higher profit margin. Car manufacturers often used fixed automation to produce one variant of a car. Tooling and robotics were developed to suit this manufacture and to change the variant would come at quite the cost. Brand, P (2020) explains that planned downtime in manufacturing often consists of set up and adjustment prior to testing, however there is often a high amount of cost associated with unplanned downtime which plays a massive factor in fixed automotive lines.

The first fixed automation system is thought to be the work of the Ford Motor company with the establishment of the first assembly line to manufacture ford automobiles in 1913. Figure 2 shows the prestigious ford assembly line in 1924.



Figure 2 - Fixed Automation Car Assembly Line (1924 Ford)

2.2.2 Industrial use for Programmable Automation

Programmable automation is used to accommodate batch production and allow for ease of product changeover. Programmable automation uses computer-controlled devices to monitor and control production sequences and tasks. According to EAM (2020), CNC (Computer Numerical Control) machines are a prime example of programmable automation. A program is coded into a computer's memory for each product or part machined, and the machine tool is controlled by the computer program. The only downfall of this technique is that CNC machines may still require re-tooling.

PLC's or programmable logic controllers are another example of programmable automation. PLCs are used to control a range of programmable inputs and outputs of a device with the use of a CPU. PLCs replaced the old-style relay banks in which a high quantity of relays were connected in a range of sequences to mimic logic. PLCs are used to programme devices such as robots, sensors, and pneumatics etc.

The first PLC according to Paterson, D (2022) was successfully manufactured by Modicon named model 084 which was built in 1968-69. This was a major revolution at the time as this device replaced the use of thousands of mechanical relays and could operate at fractions of the time.



Figure 3 - Programmable Automation (Mazak CNC)

2.2.3 Industrial use for Flexible Automation

Flexible automation systems integrate the use of robotics that can be quickly and efficiently re-programmed to produce a variety of products at any given time. Product demand often shifts in many industries, having a flexible automation system allows businesses to keep up with unpredictable change in demand.

According to a recent study conducted by Cross (2023), a big market for flexible automation is the “Consumer Electronics industry which has a short product run rate of 6-12 months”. Even though there is a high turnover, the company would often purchase customised automation equipment for every new product. Some systems such as “De-stacking / Loading” machines were estimated to cost anywhere between “£20,000-£40,000”, as soon as there was a product changeover, this equipment would sit idle in storage until the company could find a way to re-purpose it. Flexible automation allowed the company to easily shift between new products, limiting the amount of time spent re-tooling lines.

Some of the first flexible manufacturing systems were first patented by Jerome H. Lemelson in the early 1950s. The original designs included robot-based systems that could manufacture and inspect parts with little to no human intervention. In the late 1960’s these ideas flourished on shop floors in America (Hayes, A, 2022). Flexible manufacturing system were first introduced in machine shops where parts were machined and transferred between stations automatically.



Figure 4 - Tesla Flexible Automation Line

2.3 Automation History

2.3.1 Automation: The Beginning

1913 was the introduction of the first car production line by Ford Motor Company. Prior to the introduction of the assembly line, single cars were built by several skilled and unskilled workers in one space (BrightHub, 2023). The assembly line is noted as one of the first forms of automation. Production time was cut from twelve hours to one and a half hours per car. This assembly line was the first form of fixed manufacturing automation. Companies from this point on began to see the financial benefits of automating manufacture.

2.3.2 Further Advancement

Japan is noted to have introduced the first micro-switch, protective relays, and an electrical timer during the 1930s (AutoMate, 2018). Microswitches integrated into the assembly lines to operate actuators slowly eliminating labour intensive manufacture. Automation was relied upon in the production of vehicles to fuel the war effort during World War Two. Upon Japan's surrender to America and the Allied forces in 1945, an industrial program was initiated relying heavily on new technologies. Japan would slowly become world leading in the automation sector with companies like Honda, Toyota, and Nissan.

2.3.3 Modern Developments

The introduction of the Electronic Numerical Integrator and Computer (ENIAC) in 1946 and the Universal Automatic Computer (UNIVAC) in 1951, automation became far more intelligent (Groover, P, M, 2023). This invention allowed for mass data storage and quick in-process calculation. The introduction of the PLC allowed automation lines to replace mechanical relay banks with smart programmable logic to further speed up and optimise manufacturing systems.

Sensors such as inductive, capacitive and laser have all contributed to having automatic feedback control in production lines. This feedback control is crucial for real time data in an environment that is continuously changing and unpredictable.

The first company to utilise robotics in the manufacturing sector was General Motors in 1962, this robot was known as the UNIMATE (Davids, M, 2022), a 6-Axis articulated robot able to complete assembly tasks. In the present-day robotics play a key role in both flexible and fixed automation, used to react to changes in product demand as well as increase productivity and overall profit.

2.4 Advantages and Disadvantages

2.4.1 Automation VS Traditional Manufacturing

Worker Safety is said to be one of the leading reasons many industrial manufacturing companies choose to automate (Smith, J, R, 2023). Upon the passing of the 1974 HASWA (Health and Safety at Work Act) there was a big push to automate processes to reduce any company negligence.

The main notable advantages of automation over traditional manufacture are as follows:

- Productivity Increase.
- Efficient material use.
- Better product quality.
- Improved safety.
- Reduced lead times.
- Control and product consistency

The main disadvantage of automation in manufacturing is the replacement of people. The more that businesses push productivity levels, the more that machines will be used over human labour. Machines are very much programmed to complete tasks; humans can adapt to a variety of tasks. There is often high initial investment in automating manufacturing tasks, which most companies cannot afford (CraftForce, 2023).

2.4.2 Fixed, Flexible and Programmable

Fixed automation comes with high initial investment, configuring a line to automate just one product is often seen as a limiting factor. However, this is relatively useful to companies that want high production output and low cost. Companies such as Coca-Cola use hard automation to produce their product at super speed whilst maintaining staggering consistency in quality (CF Ltd, 2020). According to (Business Insider, 2023), 1.7 billion servings of Coke products are consumed every day, Coca-Cola use hard automation to meet demand.

Programmable automation has the flexibility to change between products. This is done by controlling the process through a program and can be coded to change sequences. The food industry use this to produce different variants of food. The main advantage of programmable automation is the flexibility to change products. However, it is often time-consuming and expensive to change between products and production levels are not as high as hard automation (CF Ltd, 2020).

Flexible Automation also coined as soft automation offers companies of varying products greater market share. A company can offer a range of products while still being able to meet demand. Flexible manufacturing also lowers the labour input and inventory levels (Pondent, S, C, 2017). Another advantage is that the business is regarded as working towards a factory of the future which can be greatly attractive to investors. A downfall however is the initial investment, sophisticated equipment comes at a cost. Certain products require more than just a flick of a switch, companies will still need to re-tool/re-program which can lead to down-time.

2.5 Types of Control Systems

2.5.1 Automated Power Plant

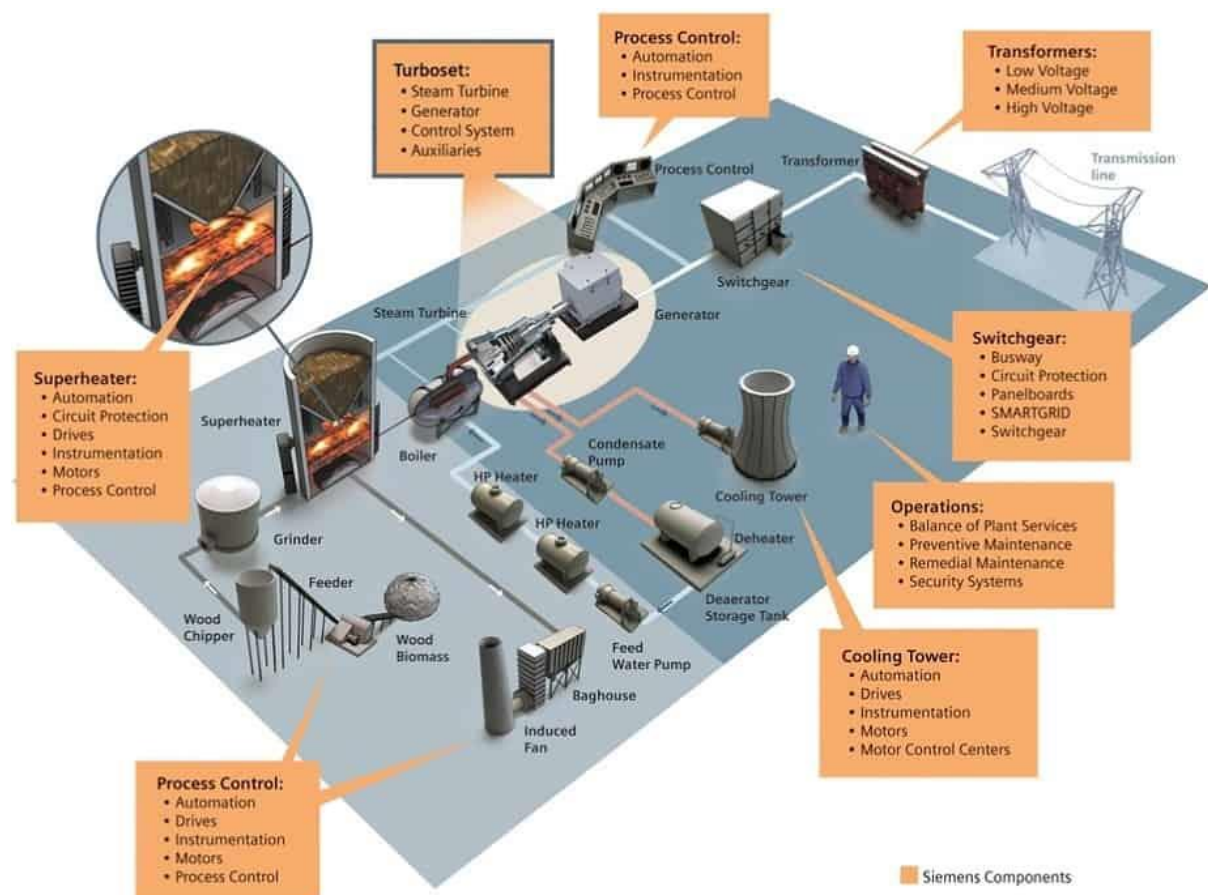


Figure 5 - Fixed Automation Plant Diagram (Electrical Technology, 2023)

Figure 5 shows an automated power plant by Siemens for achieving sustainable and safe operations (Electrical Technology, 2023). The following plant diagram is an example of fixed automation. This modernised system only serves to produce one product which is power. This provides total integrated automation using devices such as field sensors and actuating devices all controlled through PLC.

If the process required changing, this fixed system would need complete re-tooling and programming. The main advantage of this automation system is the elimination of health and safety risks that are inherent within the power industry. There is high initial investment for a system of this magnitude however this pays off with high production rates all modelled towards maximum output.

2.5.2 CNC Machining

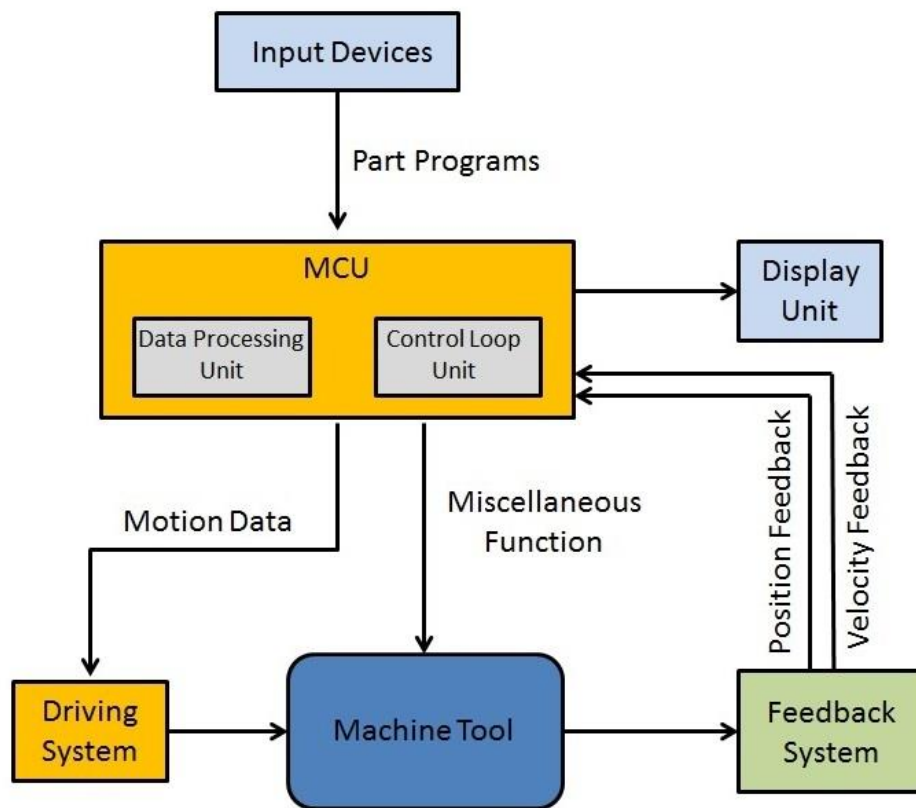


Figure 6 - Block Diagram for a CNC Machine (Mishra, P, 2023)

Figure 6 shows a standard block diagram for a CNC machine also known as Computer Numerical Control; this type of machining is a common method used worldwide. A CNC machine is a prime example of programmable automation, parts are produced via a program that is loaded into the machine. However, this machine will need re-tooling and re-programming upon changing over to machining a different part.

Some of the process variables include input devices which is often RS-232 connection to load the software to the MCU, The MCU itself is described as the heart of the machine which decodes the code loaded. The machine tool includes the spindle which holds the tool as well as the machines table, The driving system often comprises of amplifier circuits and positional data fed to the machines axis.

The feedback system is the measuring system that uses transducers continuously monitoring position and speed of the cutting tool. The MCU receives the feedback and makes relevant adjustments (Mishra, P, 2023).

2.5.3 Flexible Machining Automation

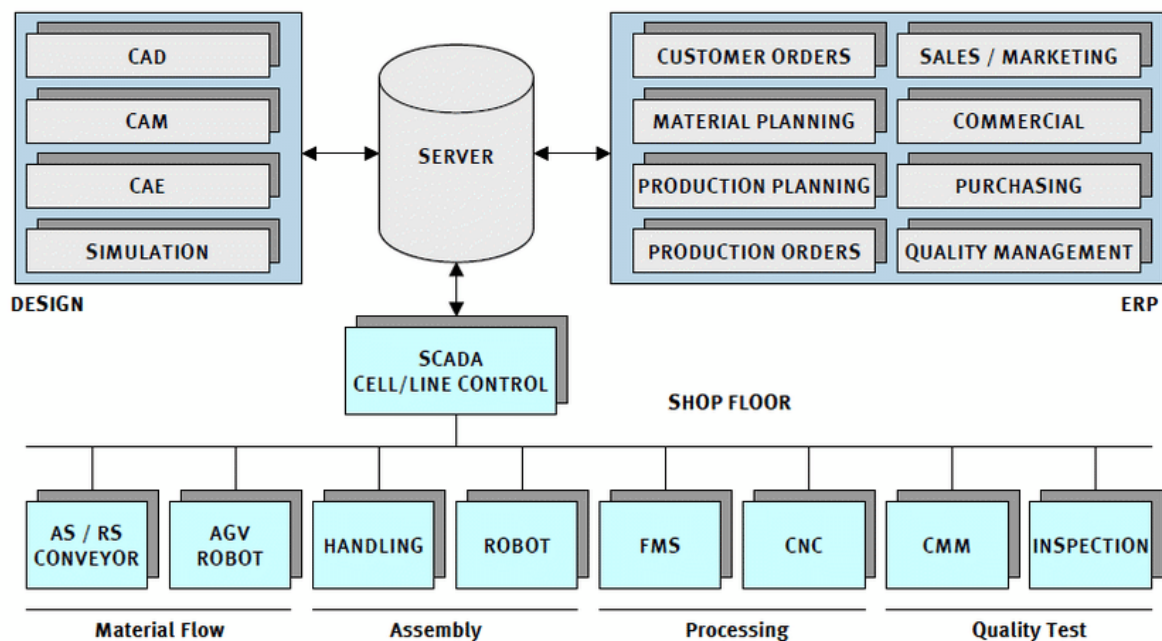


Figure 7 - Flexible Machine Shop Automation System (Kostal, P, 2011).

The following block diagram shows the flexible manufacturing system for a machine shop. This machine shop manufactures shafts, flanges, and brackets in a range of different sizes and materials. The whole process runs completely automatically, the storage conveyors load parts onto AGV's (Automated Guided Vehicles) which take the material to the Robot which loads the material into the CNC machine. The part is then unloaded taken to inspection using a CMM (Co-ordinate Measurement System), confirming the quality of the part.

This FMS (Flexible manufacturing system) as with most FMS systems is a group of numerically controlled machine tools, interconnected by a central control system. As Kostal, P (2011) describes, "Operational flexibility is enhanced by the ability to execute all manufacturing tasks on numerous parts in small quantities at a much faster delivery rate". This is the beauty of flexible manufacture, in batch production a change in demand leads to competition. Being able to adapt as a company far quicker is the difference between customer satisfaction and dissatisfaction.

2.6 Employing Flexible Automation in Flat Pack Manufacturing Industry

A world leading flat pack producer is IKEA. IKEA do not however manufacture their own parts; these are sub-contracted. IKEA (2023) explain that “products are manufactured around the world” and “use more than 1200 local furniture suppliers”. Having identified this, this section of the report will look at how IKEA could manufacture its own products using flexible manufacturing automation. Having researched further, the author identified that the main material used by the company is particleboard (Tibble, 2023).

The flat pack industry is fuelled by new and exciting designs. IKEA must change designs to keep customers satisfied. This turbulent industry means that flexible manufacturing is the perfect solution. The below figure shows a proposed manufacturing shop layout.

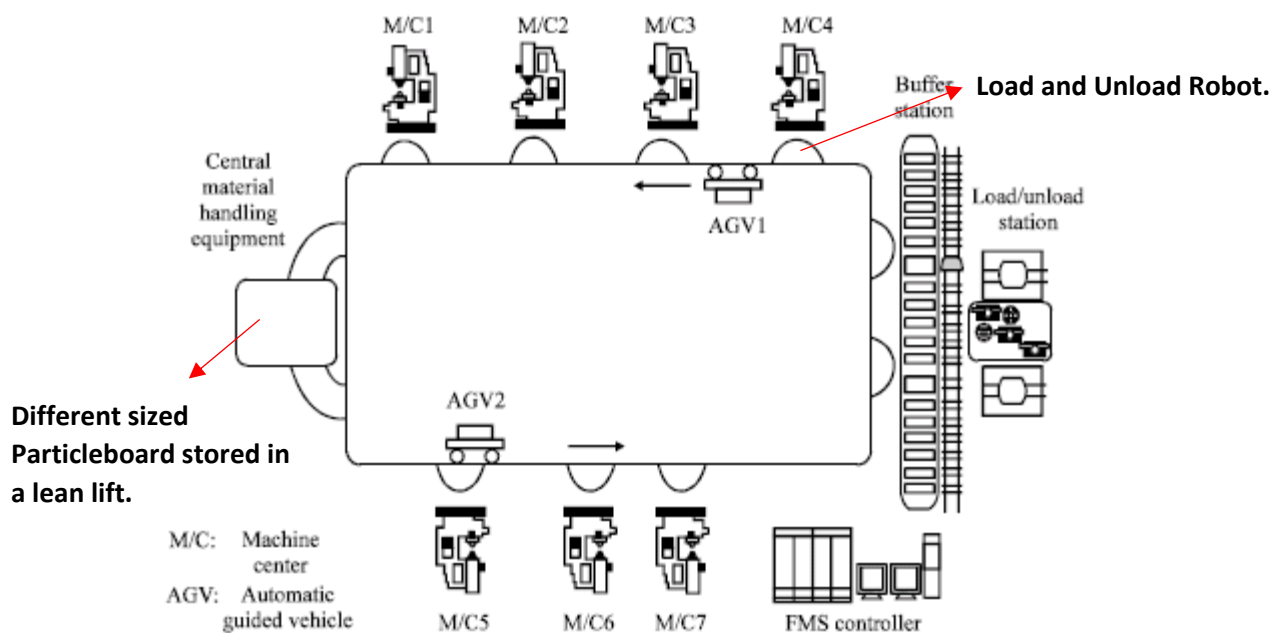


Figure 8 - Flexible Manufacturing Shop (Buzacott and Yao, 1986)

The design utilises advanced robotics, AI and computer vision systems to automate the manufacturing process. The robots that are illustrated as domes are used to load and unload the AGV's and CNC machines as well as loading and unloading to the conveyor shown on the far right.

Having completed research, IKEA already have an automated packing line so the conveyor could be a route to this. A lean lift will be used to store various sizes of particle board which will be picked up by the AGV's depending on the size ordered. The AGV's will then route to the CNCs for machining. The beauty of this layout is that a range of products can be produced on each machine at the same time.

The Robots and AGV's will communicate through a centralised computer system, which will act to co-ordinate actions ensuring steps are completed in systematic order. This allows for greater flexibility in the production as the robots will adapt to varying products without requiring re-design and retooling.

Overall, this flexible automation solution can greatly improve the efficiency and accuracy of flat pack furniture production. This can be integrated in line with the already established packing line, reducing costs, and increasing flexibility to an already volatile consumer market.

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