

ACMA5001 Control & Automation
Development and Application of Manufacturing Automation



Name: Chris Beddoe (2114310)

Date: 19th April 2024

ACMA5001 Control & Automation

Development and Application of Manufacturing Automation

Chris Beddoe

University of Wales Trinity Saint David

19 April 2024

Executive Summary

This assignment examines modern manufacturing automation, aiming to provide a comprehensive exploration of fixed, programmable, and flexible automation systems. Beginning with a historical overview, it traces the evolution of automated manufacturing from the Industrial Revolution to the modern day. Key milestones such as the advent of electricity, assembly line innovations, and the emergence of PLCs and robotics are highlighted, demonstrating the progression towards increasingly sophisticated automation technologies.

Each type of automation is examined, starting with fixed automation, characterised by its repetitive sequences tailored to produce a single product type efficiently. Examples from industries like automotive manufacturing and beverage bottling illustrate its applicability and cost-effectiveness for high-volume production with minimal variation.

Moving on to programmable automation, this report highlights the versatility enabled by PLCs and their role in supporting adaptable production processes. With the ability to reprogram sequences and parameters, programmable automation is found to suit batch production scenarios where product variety and changeovers are common.

Flexible automation emerges as the focal point, offering agility and versatility paramount for industries like flat-pack furniture manufacturing. Through robotic arms, CNC machines, and advanced control systems, flexible automation enables rapid

changeovers, customisation, and real-time quality control, ensuring efficiency and customer satisfaction.

In conclusion, while each automation type presents distinct advantages and limitations, flexible automation emerges as the most suitable choice for industries requiring adaptability and responsiveness to evolving market dynamics. By embracing flexible automation, companies in sectors like flat-pack furniture production can optimise production processes, enhance product quality, and maintain a competitive edge in today's fast-paced manufacturing landscape.

Table of Contents

1. Introduction.....	1
2. Main Body.....	1
2.1 History of automation in industry	1
2.2 Fixed Automation	3
2.3 Programmable Automation	5
2.4 Flexible automation	7
2.4 Visual overview of fixed, programmable and flexible automation.....	8
2.5 Is flexible automation best suited to a flat pack furniture company?	9
3.0 Bibliography	11

1. Introduction

In the world of modern manufacturing, automation plays a crucial role in driving efficiency, precision, and adaptability in industrial production and processes. This assignment aims to comprehensively explore the three fundamental types of automated manufacturing, these being fixed, programmable and flexible automation.

The following will also explore the historical development of automated manufacturing, the three main types of control systems and their specific process variables. It also aims to identify and discuss the intricacies of each automation system. The advantages and disadvantages of the three types of automation systems will be discussed and supported with suitable images using plant and block diagrams for the relevant systems.

Consideration will be taken as to why flexible automation may be appropriately employed by a company which produces flat pack furniture. Arguments will be made for why a flexible system would be the most appropriate type of system for this industry.

2. Main Body

2.1 History of automation in industry

The development towards automated manufacturing began during the Industrial Revolution of the late 18th and early 19th centuries, as mechanisation began replacing manual labour in factories and workshops. Water and steam power drove early automated processes, notably in textile production, where machines such as the spinning jenny and power loom mechanised and automated previously labour-intensive tasks.

The emergence of electricity in the late 19th century further accelerated businesses towards automation, enabling the use of electric motors and basic control systems. Electric-powered machinery offered greater precision, reliability, and efficiency, laying the groundwork for modern manufacturing automation. The control of electric

motors, pumps, and valves during the 1920s was very basic. The on off control of these devices was done either directly or through relays as stated by Bennett (1993).

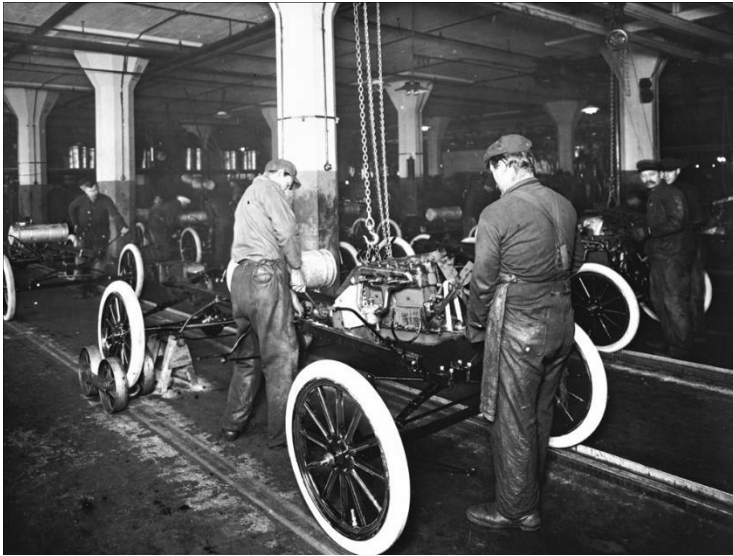


Figure 1 – First automobile assembly line. Detroit 1923 (Ford, 2023)

production. This drastically reduced production time and costs, whilst increasing output.

The mid-20th century saw the introduction of computer numerical control (CNC) systems and programmable logic controllers (PLCs). CNC machines, controlled by computer programs, enabled precise and complex machining operations, whilst PLCs provided versatile control solutions for automated processes across various industries.

Later in the 20th century saw the integration of robotics and flexible automation systems which further expanded the capabilities of automated manufacturing. Robots equipped with sensors could perform a wide range of tasks with speed and accuracy, revolutionising industries from automotive manufacturing to the assembly of smaller electronic components.

The 21st century saw the emergence of Industry 4.0, and smart manufacturing initiatives welcomed a new wave of automation, which saw the merging of digital technologies, data analytics, and connectivity. Cyber-physical systems and the Internet of Things (IoT) began transforming manufacturing environments into interconnected, intelligent ecosystems capable of autonomous decision-making and optimisation.

In the early 20th century, engineers such as Henry Ford developed innovations in assembly line production. Figure 1 shows the very first automotive production line introduced by Ford in 1923. Ford's implementation of the moving assembly line for automotive manufacturing revolutionised mass

Through these key milestones and technological advancements, automated manufacturing has evolved from its humble beginnings to become a cornerstone of modern industry, driving efficiency, productivity, and innovation on a global scale. This report aims to explore the different types of automation used today, discuss the equipment used in such systems and discuss the advantages and limitations of each.

2.2 Fixed Automation

Fixed automation, also known as hard automation, and is one of the most widely used methods of automation in industry. Henry Ford's very first automotive production line in 1913 is an early example of a fixed automation system and can be defined as a set of repetitive or fixed sequences, designed to produce a single type of product (Captech Automation, 2022). Its repeatability and efficiency mean it is well suited for businesses employing the use of assembly lines or chemical processing. These early production lines used very basic technology. Conveyor belts would transport materials along a predetermined path between workstations. Mechanical linkages and cam mechanisms were used to control timing and movement of various machine components.

An example of a company using fixed manufacturing today is Coca-Cola. Using fixed automation enables a business to produce high volumes of the same product to a consistent quality through repeatable tasks. This high level of production volume with little to no variation results in a low cost per unit compared to other types of automation. Other than bottle beverage plants such as the latter, other industries utilising fixed automation are the chemical processing industry, metal casting and foundries, printing and publishing, and high-volume assembly lines.

Due to the less complex nature of fixed automation lines, maintenance tasks are usually more basic, meaning maintenance costs can be lower. Less complexity also means the production procedures are simple to trace (CONGER, 2024). The equipment used to control fixed production lines often consists of basic logic controllers, timers, relays, sensors, and actuators to coordinate the operation of the machinery or equipment used. This equipment is often hardwired or programmed

directly into the control system with very little provision for reprogramming or customisation.

(Midwest Engineering Systems, 2024) state that fixed automation systems are better suited for: -

- Automated assembly machines.
- Chemical manufacturing processes.
- Material handling conveyor systems.
- Machining transfer lines.
- Paint and coating automation processes.
- Web handling and converting systems.

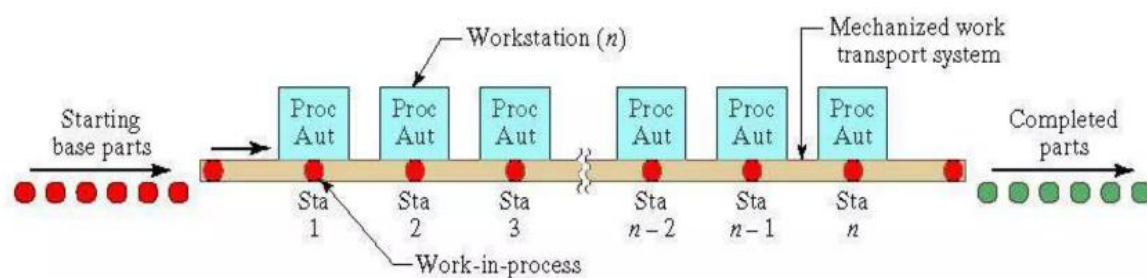


Figure 2 – Automated transfer line (Manoj, 2018)

Figure 2 is an example of a fixed automation transfer line. It shows how base parts, or raw materials, are processed through multiple automated stations within the line. Each station has its own operations assigned to it, and the part must pass through all operations to become a finished product.

Fixed automation systems require a large investment for initial installation. Along with the high installation costs, fixed automation units require modification or replacement when new tasks are required to be completed, meaning further significant investment is required should a change be made to the desired finished product. Accommodation of change is limited for these systems and therefore businesses utilising fixed automation usually have longer product lifecycles. (CONGER, 2024).

2.3 Programmable Automation

Programmable automation began with the development of programmable logic controllers (PLCs) in the late 1960s. PLCs are programmable solid-state devices with the ability to replace hardwired relays and timers with compact devices capable of executing programmable logic control as stated by c3controls (2024). C3controls (2024) also states that the first commercially successful PLC was the Modicon 084, developed and introduced by Bedford Associates. The Modicon 084 was the first PLC to incorporate ladder logic, other types of control at the time were done with boolean logic and was more suited to computer programmers. Using ladder logic

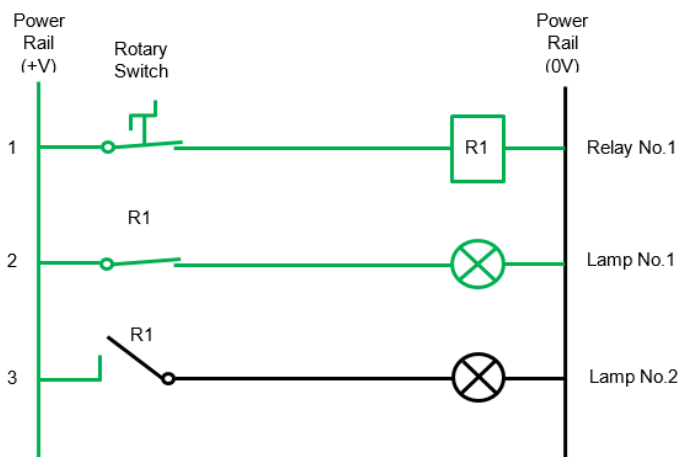


Figure 4 – PLC logic diagram, (ladderlogicworld, 2023)

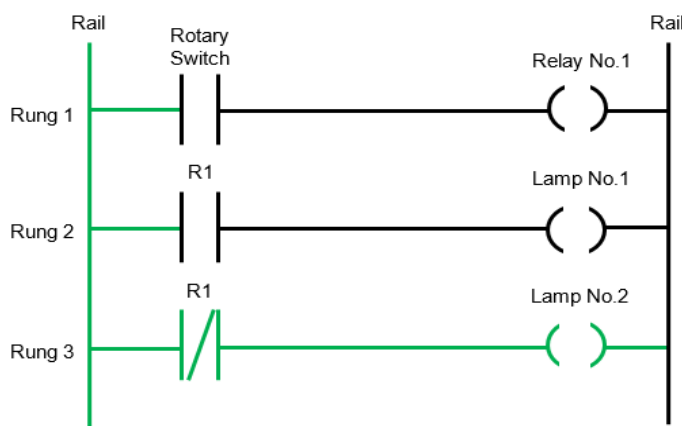


Figure 3 – Relay logic diagram, (ladderlogicworld, 2023)

meant that it was easier for engineers, who were used to working with relays and ladder drawings, to understand. See figure 3 and 4 to observe similarity between relay ladder diagram and PLC ladder diagram. Both diagrams technically do the same thing. The relay logic uses a rotary switch hardwired to a relay, and the PLC ladder diagram uses a signal from the rotary switch to the input module for the PLC. To modify the system using relay logic, you would have to rewire it, which would be time consuming and costly. To make a modification in the PLC system, it would simply require reprogramming.

By using PLCs, programmable automation enabled production lines to have more versatility and flexibility than fixed automation lines. As explored, PLCs can be

reprogrammed to modify the sequence of operations, adjust parameters, and adapt to change in product requirements. This makes programmable automation a good option for a business that requires high product volumes, has variety in its products, and have medium length product lifecycles. According to Shoplogix (2024), programmable automation is best suited to batch production. An example of which is given as “Imagine a bakery that churns out a batch of baguettes in the morning, then switches over to baking whole grain loaves in the afternoon. That’s essentially what programmable automation does”.

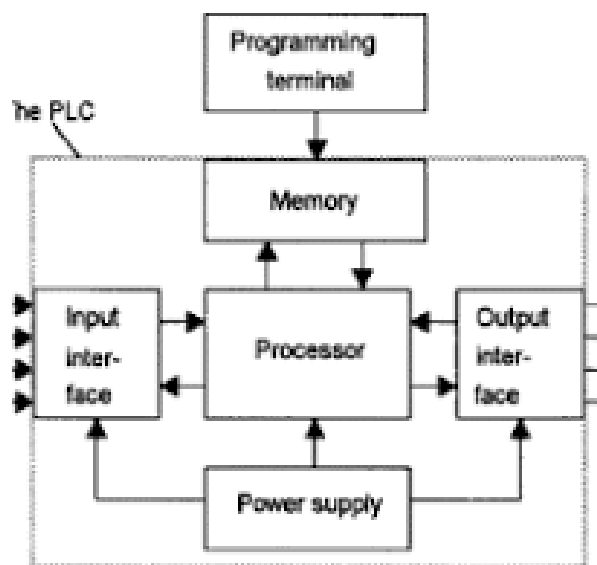


Figure 5 – PLC block diagram, (Bolton, 2009)

Figure 5 depicts a simple PLC block diagram. This block diagram shows the basic structure of how a PLC works and is programmable. A program is loaded into the PLC, and depending on the inputs to the PLC, depends on the outputs triggered. Programs can be stored and uploaded, again assisting to minimising downtime during changeovers.

Equipment used in programmable automation can range from industrial robotic arms, conveyor systems, computer numerical control (CNC) machines, vision systems and more. Due to the high-tech equipment used in programmable automation systems, initial costs are also high. Resources would be required for the equipment, relevant software, and training of employees to use such systems and software (Shoplogix, 2024). Medium to high batch production volumes is often associated with programmable automation due to the flexibility of changing products compared to fixed automation, although periods of downtime are required to be accounted for when using programmable automation as tooling changes are often required when changing batches of product. Overall, programmable automation systems are designed to be easily reconfigured or reprogrammed to accommodate businesses that require changes in production requirements, product designs, or process parameters.

2.4 Flexible automation

The concept of flexible automation, also known as soft automation, emerged in the 1980s due to advancements in robotics, control systems, and computer technology which enabled greater reconfiguration and adaptability in industrial automation systems. Flexible automation systems are characterised by their ability to adapt quickly and easily to changes in production needs, product designs, and process requirements. Flexible automation systems typically incorporate programmable components such as industrial robots, CNC machines, and flexible manufacturing cells. Industrial robots, equipped with sensors, vision systems, and advanced control algorithms, play a central role in flexible automation. These systems can perform a wide range of tasks with high precision and flexibility, making them well-suited for applications such as complex assembly, material handling, and low volume or one-off bespoke product manufacturing.

Industries utilising flexible automation vary from the automotive industry and electronics manufacturing. CONGER (2024) highlights that “flexible automation allows the production of different product types without the need for complex reprogramming. This allows production to switch between tasks minimizing downtime”. It also means that a business can adapt to rapidly changing market environments. For example, a toy manufacturing business that uses flexible manufacturing could “the same robot used to produce toys can be making plastic trucks on one day and action figures on the next”, according to CSD Automation (2021).

Industries utilising flexible automation benefit from its flexibility, meaning there is no longer a need to create multiple identical products in batches, although it can do so if required. This is due to the ability to change product automatically without complex changeovers. This means businesses can cater to customers needs with high levels of customisation of products, usually run in small volume, or custom “one off” products.

The advanced robotics used in flexible automation comes at a high cost and is more expensive than opting for fixed automation. This means high startup costs. However, businesses will be able to make their money back by reducing production

costs with the help of the effect robots. So, businesses will have to weigh their options to decide if they can weather the storm of expensive startup costs (CSD Automation, 2021).

Utilising Flexible manufacturing often involves trade-offs in terms of speed, efficiency, and throughput. While flexible automation allows for rapid changeovers between product configurations, it may result in slightly lower production speeds or higher cycle times compared to dedicated production lines optimised for specific products.

2.4 Visual overview of fixed, programmable and flexible automation

Table 1 below, and figure 6 overleaf, give a basic visual overview of the three types of automation discussed. These tables and images show how the type of automation used will depend heavily on a business's needs and what volume and variation of products will be required to be produced.

	<i>Initial investment</i>	<i>Production rates</i>	<i>Flexibility</i>	<i>Production type</i>
Fixed automation	high initial investment for custom-engineered equipment	high production rates	relatively inflexible in accommodating product variety	fixed type of product
Programmable automation	high investment in general purpose equipment	lower than fixed automation	flexibility to deal with variations and changes in product configuration	most suitable for batch production
Flexible Automation	high investment for a custom-engineered system	medium production rates	flexibility to deal with product design variations	continuous production of variable mixtures of products

Table 1 - The comparison of three type of production automation, (Groover, 2001)

What is evident is that according to Groover (2001) all three types of automation incur high start up costs. This point highlights how important it is to choose the correct type of manufacturing before such a large investment. Production rates,

flexibility and type also vary between the three, as explored in sections 2.2, 2.3 and 2.4.

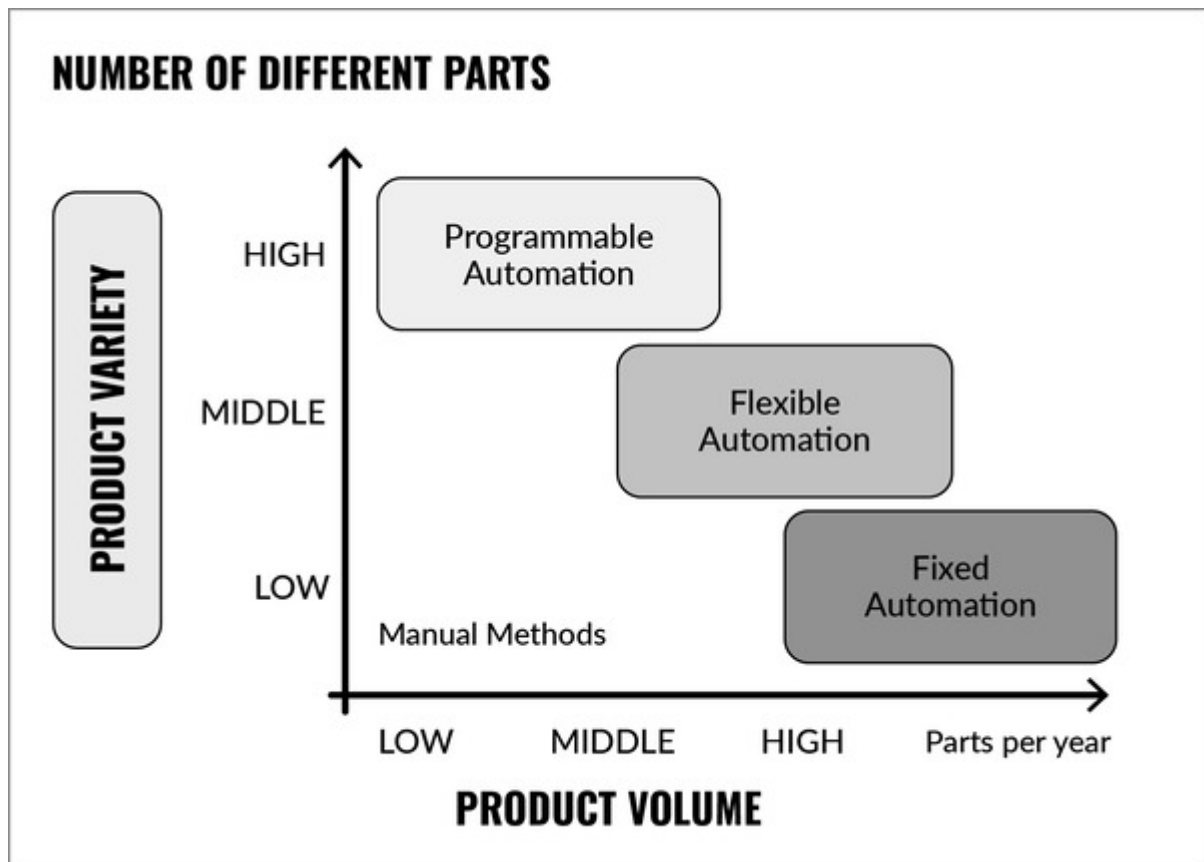


Figure 6 – Image depicting which type of automation method best suits which type of product. (CONGER, 2024)

2.5 Is flexible automation best suited to a flat pack furniture company?

As discussed, flexible automation refers to the use of automated systems that can adapt to different tasks, products, or production volumes without the need for extensive reprogramming or retooling. In the context of producing flat-packed furniture, flexible automation can offer numerous advantages due to the ability to cope with variability in product designs, materials, and production volumes. Since flat packed furniture comes in various designs, sizes and materials, flexible automation is well suited to cope with these variations without any significant downtime. For example, robotic gripper arms can handle different types of parts and materials efficiently, adjusting their movements based on the specific requirements of each product. Production volumes can be scaled up or down easily to cope with fluctuation in product demand, again without major reconfiguration. This is especially

valuable as the flat pack furniture industry tends to see differing seasonal demands or market trends as stated by Bäckman & Engdahl (2022). Flexible automated systems can adjust production rates dynamically based on real-time demand, optimising resource utilisation and minimising waste to the business. As mentioned, incorporated vision systems could also be used for automatic quality control of product meaning any variation or defects can be picked up in real time, protecting the customer and ensuring rework and returns are kept to a minimum.

3.0 Bibliography

Bäckman, M. & Engdahl, A., 2022. *Integration of Planning Functions*, Gothenburg: Chalmers University Of Technology.

Bennett, S., 1993. *A History of Control Engineering, 1930-1955*. 1st ed. London: Institution of Engineering and Technology.

Bolton, W., 2009. Programmable Logic Controllers. *Programmable Logic Controllers*, Volume 5, pp. 1-19.

c3controls, 2024. *THE HISTORY OF PROGRAMMABLE LOGIC CONTROLLERS: FROM THEN TO NOW*. [Online]

Available at: <https://www.c3controls.com/white-paper/history-of-programmable-logic-controllers/>

[Accessed 26 April 2024].

Captech Automation, 2022. *FIXED AUTOMATION SYSTEM: WHAT IT IS AND ITS APPLICATION IN MANUFACTURING*. [Online]

Available at: <https://www.captechautomation.com/blog/fixed-automation-system-application-manufacturing/>

[Accessed 23 April 2024].

CONGER, 2024. *6 Types of automation [Benefits, Pros/Cons and examples]*. [Online]

Available at: <https://www.conger.com/types-of-automation/>

[Accessed 24 April 2024].

CSD Automation, 2021. *THE DIFFERENCE BETWEEN FIXED & FLEXIBLE AUTOMATION*. [Online]

Available at: <https://controlsdesign.com/blog/the-difference-between-fixed-flexible-automation/>

[Accessed 27 April 2024].

Ford, 2023. *First Automobile Assembly Line. Detroit 1923*. [Online]

Available at: <https://media.ford.com/content/fordmedia/fna/us/en/features/game-changer--100th-anniversary-of-the-moving-assembly-line.html>

[Accessed 20 April 2024].

Groover, M. P., 2001. *Automation, Production Systems, and Computer-integrated Manufacturing*. 2, illustrated, reprint ed. s.l.:Prentice Hall.

ladderlogicworld, 2023. *Relay Logic Vs Ladder Logic*. [Online]

Available at: <https://ladderlogicworld.com/relay-logic-vs-ladder-logic/>

[Accessed 27 April 2024].

Manoj, K., 2018. *ANALYSIS OF TRANSFER LINE WITH BUFFER STORAGE*, Bengaluru: M S Ramaiah Institute Of Technology.

Midwest Engineering Systems, 2024. *Fixed Automation Systems*. [Online]
Available at: <https://www.mwes.com/capabilities/assembly-and-automation/fixed-automation-systems/>
[Accessed 25 April 2024].

Shoplogix, 2024. *What is Programmable Automation?*. [Online]
Available at: <https://shoplogix.com/what-is-programmable-automation/>
[Accessed 3 May 2024].