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The missing 11%: Utilising robotics and Automation to
fill the gaps of labour shortages and attendance
inconsistency.

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How will I go about my dissertation?

Abstract

With the manufacturing environment continuing to be volatile in regards to long term stability, its common for businesses to turn to temporary labour to fill voids in the workforce. There are pros and cons to this type of staffing but unfortunately the percentage of negative impacts outweighs the positives in relation to business impacts. To address the impacts of having to use a temporary labour this dissertation will investigate various industry 4.0 methods available to help manufactures “fill the labour gaps” in this instance the missing 11%. Literature and journals will be reviewed along with closely following lean six sigma and continuous improvements suggestions and solutions.

Case studies will be closely be studied of instances where automation and Robotics have both succeeded and failed or not had the desired impact that was wanted for the money that has been spent. Special focus will be applied to solutions that are not off the shelf and bespoke and also a look at how plastics manufacturing specifically extrusion has been left lagging other industries with the implementation of technology and Automation.

Commonly available trade magazines and social media pages often highlight struggles that business have in implementing technology but rarely do the root causes of labour shortages or efficiency become highlighted as the reason behind changes being made. Quite often Automation and Robotics are highlighted as a solution to reduce labour cost where this dissertation explores the way automation and Robotics works in collaboration with staff in an ethical way. The last subject to be touched upon will be the costs involved and financial analysis for the cost of implementation against the benefits seen in automation and Robot investment.

About the Author

The author of this dissertation joined Berry global 10 years initially as engineering manager and for the last 7 years also taken on the role of Business excellence which in turn complements Engineering. A core function of Business excellence entails lean six sigma, R and D (Research Development) and innovation. The role involves supporting departments with advice and guidance on improvement area along with highlighting any innovative projects that can support efficiencies at site. On top of that the Author is the Site representative for the Berry Industry 4.0 programme leading monthly communications and initiatives to the wider group.

Academically the Author undertook a Multiskilled Engineering apprenticeship with a food manufacture that at the time had the most advanced fruit processing plant in Europe thus Automation was introduced at a very early stage along with achieving a foundation degree followed by institute of leadership and management diplomas.

From an Engineering perspective the author has always been involved in or led R and D or innovation projects. Following the completion of the apprenticeship, shift work was short lived before being selected to be part of a project team involved in a multimillion pound project. On completion of the project the author then had the task of ensuring key KPI's were achieved on the installation. The author Joined Berry with the scope of modernising a company that had little or no modern automation and almost all machinery relied on mechanical processes. Uptime was under 80% and recovery times lengthy. Quite quickly after highlighting root causes using 5Y analysis and FMEA (Failure Mode and Effects Analysis) the plant started to lead the way in Berry. Currently the plant achieves over 99% machine uptime year on year.

Management plays a big part of the author's professional life but the passion for continuous improvement and innovation is the motivation for continued academic studies that can be transferred to real life scenarios.

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1-Introduction

1.1-Introduction/ brief

Some businesses see their strongest sales during certain seasons. For instance, a landscaping business may see brisker business during the summer, while a holiday decorating service likely has higher sales at the end of the year. Because of this, retailers and seasonal service businesses often experience annual “sales slump” periods. However, that doesn’t mean the team needs to sit idle or that there aren’t smart strategies that can strengthen the company’s financial position. Making sure operational cash flow is positive and setting aside reserves before the slow season hits is critical to business success. (Forbes, 2023)

Manufacturing costs are the costs incurred during the production of a product. These costs include the costs of direct material, direct labour, and manufacturing overhead. The costs are typically presented in the income statement as separate line items. Manufacturing facilities incurs these costs during the production process.

Direct material is the materials used in the construction of a product. Direct labour is that portion of the labour cost of the production process that is assigned to a unit of production. Manufacturing overhead costs are applied to units of production based on a variety of possible allocation systems, such as by direct labour hours or machine hours incurred (tools, 2024)

It is these direct labour cost that this dissertation will be researching in particular how a business will use temporary labour to offset retaining full time staff all year when line capacity is reduced as sales reduce and the challenges that bring resulting in the “missing 11%”.

It is well documented that temporary labour poses business risk for a number of reasons such as temporary labour lacking basic skills necessary for satisfactory workplace performance in productivity and safety. Also integration with permanent staff can be an issue in some cases leading to conflicts. Evidence also suggest that temporary labour attendance levels are not guaranteed so for facilities that are required to hit production orders inconsistencies in attendance percentages pose a big risk to business.

1.2-Aim

The aim of this dissertation is to provide a scope of how industry 4.0 technology can benefit manufacturers by improving manufacturing output, reducing costs yet still remain ethical.

The dissertation will investigate the challenges such as cost, bespoke solutions and lack of skills in the labour market regarding implementation and fault finding new technologies.

1.3-Objective

Specific area within scope of the dissertation will be analysed through literature review and case studies of the relevant areas and journals. Key Objectives that fall into the dissertation scope are:

- Analysis of Technology in extrusion
- Analysis of automation and Robotics in Wales
- Analysis of the labour market in Wales
- Analysis of local innovation

1.4-Justification

Increased production demands usually highlights the need for further labour. In cases where that labour tends to come from a temporary workforce. This means staff that are not contracted to regular hours but are called upon when needed. Where business is uncertain on volume month on month this seems a viable option. It does however come with a raft of inefficiencies. COVID has also taught us, keeping a full staff of trained and qualified operators can be a challenge. Consider the basic concept of Lean Manufacturing where by efficient and competitive production is the aim and waste is minimised as much as possible. The most profitable operations minimise waste and optimise their biggest resources. Many initiatives promote maximum throughput and profits while ensuring their manufacturing processes are focused on quality and value adding tasks. When a balance sheet/income statement is scrutinised Raw material, machinery and people are the biggest costs. In a world where everyone wants things faster and cheaper, every manufacturer needs to keep eyes on the goal of how to deliver the highest quality product with the best, most favourable margin. In businesses where there is a high reliance on people and attendance rates challenging, it can be very difficult to ensure those favourable margins are achieved. If production has to stop due to lack of staff then Justifying Automation and Robotics can be quite easily quantified.

1.5-Methods

Reviews of literature are necessary in order to provide accurate up to date information whereby they involve summaries and synthesis of primary research findings on a particular topic of interest and can be grouped into two main categories with major differences between them:

- The traditional review
- The systematic review

Traditional reviews provide a broad overview of a research topic with no clear methodological approach. Information is collected and interpreted unsystematically with subjective summaries of findings. Authors aim to describe and discuss the literature from a contextual or theoretical point of view. Although the reviews may be conducted by topic experts, due to preconceived ideas or conclusions they could be subject to bias.

Systematic reviews are overviews of the literature undertaken by identifying, critically appraising and synthesising results of primary research studies using an explicit, methodological approach. They aim to summarise the best available evidence on a particular research topic.

The main differences between traditional reviews and systematic reviews are summarised below in terms of the following characteristics: Authors, Study protocol, Research question, Search strategy, Sources of literature, Selection criteria, Critical appraisal, Synthesis, Conclusions, Reproducibility, and Update (Demeyin, 2016).

1.6-Ethics

The basic forms of machine automation have long raised concerns for the employment prospects of sectors of the population engaged in routine assembly tasks. Many repetitive manufacturing tasks once requiring human labour have already been replaced by robots. The general public are facing associated risks to safety and privacy with the appearance of drones, driverless cars, robots of care, and human repair and enhancement (Iphofen & Kritikos, 2018).

2-Culture

2.1- Organisational culture

Every organisation, regardless of region, country or sector, has a culture of its own. Company buyouts/mergers do not always succeed and depending on the type of workforce and company values along with parent company ideas success or failure is not initially clear to see. In the late 90s the world's car industry had to face a number of challenging problems.

The permanent overcapacity of many carmakers, the strengthened position of the clientele and the rising environmental consciousness threatened the existence of a number of car producers.

In 1998 when faced with the demanding and rising challenges on the car market Daimler-Benz and Chrysler decided to merge as the two companies were thought to complement each other. The strengths of one of the partners were supposed to offset the weaknesses of the other. (Julia, et al., 2011). The merger of the two companies was supposed to provide a shared goal and both parties involved in the deal hoped for gaining competitive advantages thanks to newly created synergies. The merger was considered a merger of equals, but soon it became obvious that this was not really the case as both parties were never truly willing to cooperate wholeheartedly to accept changes or enter compromises in order to make the merger a success.

It's crucial to identify and to define precisely common goals and to elaborate certain norms and regulations for business processes. Furthermore a good and far-reaching communication strategy is Indispensable (Julia, et al., 2011).

In an old mining town such as Aberdare very similar issues have been seen when company accusations have taken place. The move from private to corporate has still not been accepted by some staff and change management is a constant battle where at times until increased revenue or investment into site is proven the change culture is one of negativity. Similar battles are expected with moving from a labour reliance operation to an automated and collaborative operation. There are examples where acquisition has had positive impacts unlike Daimler Mercedes. Innocent drinks is a company born in the late 90's and in a very short time grew to a \$500 million company. A trio of university graduates stated to sell Juice at a music festival before marketing they're product in a very modern and unique way. As Innocent made inroads into the drink Market they were bought out by a multinational namely Coca cola. Coca-Cola completed its takeover in 2013 as part of a deal that reportedly valued Innocent at £320 million after first taking a majority share in 2010. Directors at Innocent reported that there had been zero pressure from anyone at Coke to change Innocent's model, despite admitting the company ran in a highly illogical way. (Bodkin, 2015). New products

boosted sales by £28 million. Revenues continue to rise prior to the takeover with the revenue was reportedly £247.4 million – an increase of 13% on the previous 12 months (Tucker, N/a) .

Organisational culture can have positive and negative impacts but are a major influencer of the success of any project. Given the previous experience of managing change at Berry after a major change such as an acquisition we have a very good gauge of what needs to happen with an innovation change. Culturally the workforce will need to be prepared for collaboration with robotics.

2.2 Company history

In 1985 Tubex invented the original tree shelter, producing the first PP twin walled tube, and over the next few years launched the unique features that characterise Tubex shelters to help establish young saplings. Recent innovations include a tree shelter collection and recycling scheme nationwide free of cost, and bio polymers as part of environmental efforts.

In recent years Tubex has achieved significant sustainability milestones, such as the implementation of recycled content in recyclable range, currently at an average of 35%. Latest achievement was the launch of the Tubex Nature biodegradable range in 2021. Tubex continue to serve the forestry, landscaping, viticulture, and fruit markets globally with the most comprehensive plant protection portfolio, commitment to pioneering innovation and sustainability remains steadfast so Tubex can continue advancing growth for our planet. (Tubex, 2023).

Back in 1985 Tubex moved production from a laboratory environment in London to a factory environment in Aberaman as part of a scale up exercise. Since then the company gained further investment from a consortium of local business men and was very much a family environment style company. Those days are now gone with the company coming under co-corporate ownership first up by Fiberweb Geosynthetics then PGI before now being owned by Polymer giants Berry global as part of a \$7.6 Billion company. Tubex remains a very big employer in the Cynon Valley with over 120 employees and year on year growth in an area that is still considered deprived.

2.3 Area culture

Post Covid analysis by the National Institute of Economic and Social Research (NIESR) as part of the quarterly UK economic outlook shows that unemployment rates in Wales was projected to rise sharply over the period 2021-2023 to about 6 per cent or above, compared to UK average of 5.2%. Together with unemployment, labour force participation is also under stress. Wales was projected to have sharp rises in economic inactivity throughout the period 2021-2023, with projected inactivity

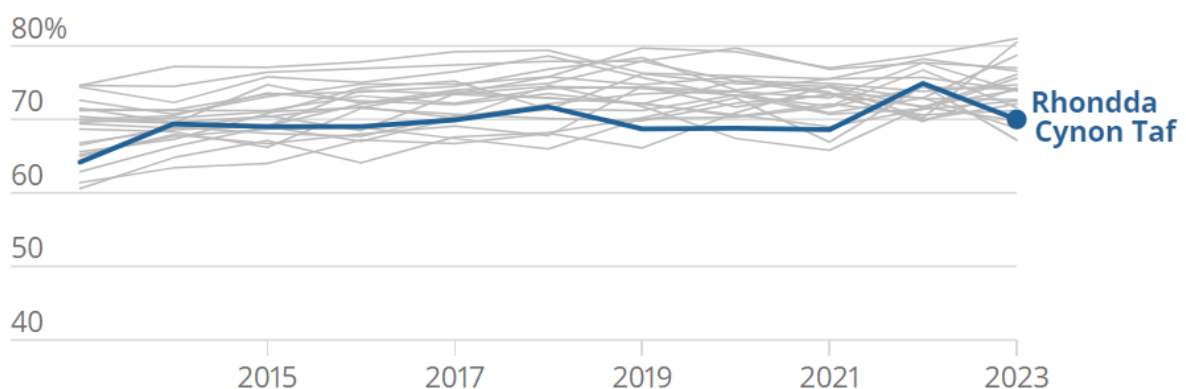
rates rising to above 40 per cent over the period, compared to the UK average of 37% (research, 2021).

Rhondda Cynon Taff's employment rate was lower than across Wales as a whole in the year ending June 2023. Of people aged 16 to 64 years living in Rhondda Cynon Taff, 69.6% were employed in the year ending June 2023. This is a decrease compared with the year ending June 2022 when the local rate was 75.1% (statistics, 2023). Around 40,400 people or 27.3% of the population aged 16 to 64 years in Rhondda Cynon Taff were "economically inactive" in the year ending June 2023. This compares with around 34,300 people (23.0%) in the year ending June 2022. People are classed as "economically inactive" if they are not in employment but don't meet the criteria for being "unemployed". This means they have not been seeking work within the previous four weeks or were unable to start work within the next two weeks. Common reasons include being retired, looking after the home or family or being temporarily or long-term sick and disabled (statistics, 2023).

Rhondda Cynon Taff is a relatively small area and when the Cynon valley is broken down into its own valley the pool of people who look for work in manufacturing or are actively looking for work is very small. To further add to this retention rates for unskilled labour is not favourable for manufactures as is proven in the missing 11% workforce seen year on year.

Employment rates of areas in Wales

Among those aged 16 to 64 years (%), year ending June 2013 to year ending September 2023



Source: Annual Population Survey from the Office for National Statistics

2.4-Industry culture

In industry where there is a big reliance on people and the cost of Labour relatively cheap, supplying business cases to automate can prove quite difficult. The manufacturing industry in the Cynon Valley

comprises quite heavily of plastics manufacturers and very similar business models where there is a reliance on people and a very small pool of people. In the last few years that industry culture of people reliance has changed somewhat and part of that reason is the effects of minimum wage increases. One journal suggested that increasing the minimum wage decreases significantly the share of automatable employment held by low-skilled workers, and increases the likelihood that low-skilled workers in automatable jobs become non-employed or employed in worse jobs. The average effects mask significant heterogeneity by industry and demographic group, including substantive adverse effects for older, low-skilled workers in manufacturing. Evidence also highlighted that the same changes improve job opportunities for higher-skilled workers. The findings imply that groups often ignored in the minimum wage literature are in fact quite vulnerable to employment changes and job loss because of automation following a minimum wage increase (Lordan & Neumark, 2018). This information compares with studies carried out at Berry sites where investment into Automation has taken place. There is also a potential for hours in automatable work to decrease following a minimum wage increase whereby results indicate that those in automatable low-skilled work are vulnerable to hour reductions following a minimum wage increase. This change in minimum wage had change the industry culture from people to Automation as there are now positive financial benefits due to the labour cost spiralling and Automation cost dropping.

2.5 -Leadership

A culture of leadership is not something that all companies employ and investment into leadership for Tubex as a private company was near to non-existent. Failing to address this investment fostered a culture that could be quite easily seen at the Gemba. Breaking that kind of perception of a company that don't invest in people can be challenging. Ten years into corporate ownership there is still groups of employees that don't embrace change and these are the employees that will struggle to accept the change from people reliance to Automation and could be detrimental to success.

A company that has a modern way of thinking regarding Automation has to also have a modern way of thinking into leadership. Leadership is essential in organizations to successfully promote a culture of innovation. Consequently, leaders assume a crucial role in the paradigm shift towards Industry 4.0 (Guzman, et al., 2020). For the first Industrial revolution (IR) charismatic leadership is related to how leaders act and mobilise an organisation through actions and personal characteristics. The second IR was strongly shaped by scientific management, in which leaders assume a top down style, while they could be characterised as a directive leadership. For the third IR, leadership is characterized by relational leadership, considering the theories of transformational leadership to stimulate the autonomy of followers for new ideas and collaboration among them. The third IR is also

characterised by transactional leadership more conducted and recognised by the achievements of follower's goals. The fourth IR requires both existing characteristics and new required characteristics from leadership that need to be more than a transformational leadership. It needs also a more specific focus on learning and innovation (Guzman, et al., 2020). Managing digital environments in an aging workforce requires an alignment of leadership styles focussed on digitalisation given the disruptive changes that arise with smart production systems. Smaller scale digital changes that have tested out the culture include moving from paper to spread sheets and using SCADA to collect data as appose to manual data entry. Both of which have not been accepted without pushback and lot of coaching.

Cognitive Skill (CS)	Business Skill (BS)	Interpersonal Skill (IS)	Strategic Skill (SS)
CS1: speaking CS2: active listening CS3: writing CS4: reading comprehension CS5: active learning CS6: critical thinking	BS1: operations analysis BS2: management of personnel resources BS3: management of financial resources BS4: management of material resources	IS1: social perceptiveness IS2: coordination IS3: negotiation IS4: persuasion	SS1: visioning SS2: systems perception SS3: system evaluation SS4: identification of downstream consequences SS5: identification of key causes SS6: problem identification SS7: solution appraisal

3-Technology

3.1-Technology in plastic manufacturing

The basic principles of extrusion remain unchanged, but the markets and materials, especially additives, continue to evolve. Raw material are still heated to form a viscosity of material that is lucid enough to push through dies and form a shape. The use of an extruder allows the rapid melting of the polymer in a thin film of melt, which is continuously removed exposing fresh solid for melting. In this context, the extruder becomes a unit operation in the polymer-processing industry with being the primary device used to produce molten polymers at high rates necessary for efficient and inexpensive molten polymer production. The heating process theory has barely changed over the year albeit controllers have got smarter for more efficient heating and process control (Kutz, 2017). The principle of the cooling process has also remained largely unchanged using water, air, or contact with a cold surface. A water cooling process entails water being sprayed on the extrusion at high litres per minute which allows the extrusion line to be run at higher rates. Cooling from room temperature after the product is completely solid results in additional product shrinkage and dimensional changes. To minimize differential shrinkage, the part must be cooled uniformly on all sides which in its basic form is nozzles spraying fine water mist to saturate the extrusion but not damage it. If one side or area of the extrusion solidifies before another, the part will warp bending toward the side that solidified last. If one side of the extrusion is dragged over an object in the cooling operation, molecular orientation is induced on that side of the part causing it to shrink differently from the other side leading to warpage. Cooling rates with polymers are critical in developing the correct amount and size of crystals in the final product (Kutz, 2017). Although the theory sound quite complex the mechanical aspect of a cooling tank remains very basic and unchanged since introduction. The biggest technological changes seen with these two aspect of extrusion is with process control and moving from analogue and Statistical control in the 1970's to digital controls in the 1980's before PLCs changed things in the 1990-2000's.

3.2 Technology in extrusion

Each manufacturer will have their own answers on end of line conversion depending on the end product being produced. This is where technology has the biggest impact weather it's on the conversion side, packaging or palletising of finished products. It has been well publicised and documented that Industrial automation can provide big financial gains in labour intensive manufacturing industries. One only has to think back to a time where the automotive industry were building cars by hand using masses of labour. Today almost all automotive plants are highly invested

into Robotics and automation. Drivers for this investment is the value of the end product allowing research and development into new technologies to have a strong business case. Extrusion is slightly different where by most are producing throw away one time use products that have a low retail value. High volume, labour-intensive manufacturing operations pose several challenges for successful operations. It is an even bigger challenge to move away from manual dependency and shift towards automation of production processes. There seems to be no general agreement among researchers on what are the critical success factors (CSFs) on the implementation of advanced automation and robotics processes in the manufacturing environment (Lai, et al., 2020). As previously mentioned with low value products and low minimum wage, building business cases for high value investment is difficult. Now that minimum wage and energy prices have increased along with automation cost dropping there are changes for investment into innovation particularly in conversion and packaging of products which incidentally is where the labour requirements are needed.

There is also the environmental side of plastic that is really pushing technological changes in extrusion with the introductions of Bio polymers and recycled content (RPP) addition. Since the subject of biodegradable polymers caught wide notion in the early 1970s, biodegradable polymers have received extensive investigations from academia and industry and experienced several important stages of development. Biodegradable polymers mainly include aliphatic polyesters such as polycaprolactone (PCL), polybutylene succinate (PBS), polybutylene succinate-co-adipate (PBSA). Biodegradable polymers and plastic materials from renewable resources such as starch, soy protein (SP), cellulose, and plant oil have also been developed and are quite commonly mixed with aliphatic polyesters in the same batches. Bio polymers send out the correct environmental message and historically, the research interest and effort on biodegradable and bio based polymers has been up and down, in accordance with the cycle of oil price and energy prices (Kutz, 2017). Developing biodegradable polymers from renewable resources appears to be the best scenario in the development of “green” materials and processing techniques. However, this can only be certain after carrying out a life cycle environmental impact analysis (mainly on energy consumption and CO₂ balance) on individual products. For example, to produce PLA using corn starch, the application of fertilizers, herbicides, and pesticides during the growth of corn may leave a deep environmental footprint. The chemical or biochemical processes such as extraction and purification of lactic acid require water, energy, and chemical or biological additives. The whole production process also produces various wastes which require energy and material consuming treatment and disposal. Furthermore, CO₂ is released back to the environment during the degradation of PLA. Therefore, biodegradable polymers derived from renewable resources may not be as “green” as they appeared

to be at the first sight (Kutz, 2017). Conclusion of studies and surveys we have carried out internally suggest that The Co2 impact of Biodegradable products maybe outweighed by the use of recycled content plastics as part of a more circular economy approach. Plastic that has come to the end of life, collected and reprocessed back into a plastic pellet has a much better C02 impact and in some cases is almost indefinitely recyclable.

Both Bio degradable plastics and recycled plastics are now challenging technology in order to process these polymers as efficiently as possible.

3.3 Innovation in extrusion

End of line conversion of extrusion has to be thought about in a Holistic way as and comparable to the manufacturing industry as a whole. Equipment such as material handling, pick and place, palletising and stacking are all common item that can be thought of as off the shelf in their base format. Naturally the innovation comes into the project when bespoke actions are needed. Industrial automation has evolved through many phases from automation in single production lines, to full-scale computer integrated manufacturing systems over the past decades by replacing much of labour-intensive manual processes and increasing the level of automation in many industries. New digital technologies such as the Internet of things, cyber-physical systems (CPS), and novel concepts such as the factory of the future, Industry 4.0 and cloud manufacturing (CMfg) have fuelled the hunger for further automation and maintain competitiveness in the manufacturing sector. Moreover, Industrial robotics, in the past 50 years, have significantly transformed the manufacturing industries around the world by replacing humans in various repetitive, difficult, or dangerous tasks and at present collaborative human-robot working environments are becoming increasingly popular due to enhanced flexibility and efficiency. It is further evident in the literature that these advanced manufacturing systems which enabled an increased level of automation in the shop floor have paved the way to achieving the goal of fastest time-to-market, highest quality, lowest cost, best service, greenest environment, maximum flexibility, and highest knowledge for modern manufacturing enterprises (Lai, et al., 2020). Its been predicted that not just conversion but now Extrusion technology will evolve with industry 4.o over the next 10 years and with the integration of auxiliary equipment communication with extruders as part of a process. Within plastics, sectors such as injection moulding, blow moulding and melt blowing have embraced industry 4.o innovation and have been leading the way but now extrusion and compounding are catching up using similar blue prints.

4 - Automation and Robotics

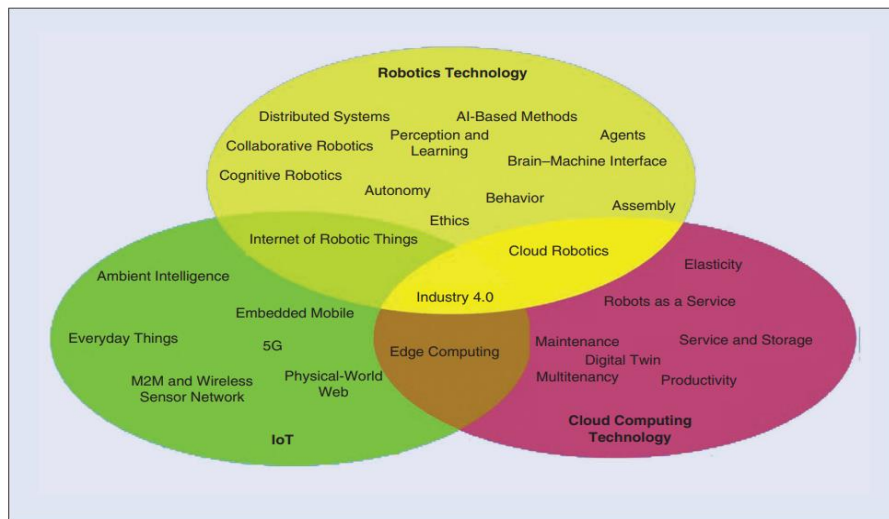
4.1-History

Growing up in the 80s and 90s films such as Robocop, Terminator and a little later the Matrix all foster an idea of what Technology and robotics could become. Within industry Robotics are aligned with replicating the movements and replacing the tasks that humans would have historically had to do. In cases where tasks are repetitive, dangerous or heavy robots have many positives albeit does come with ethical concerns over job losses.

Robots have been part of automation systems for a very long time, and in public perception, they are often synonymous with automation and industrial revolution. Leading up to the 1980's automation and robotics were in the form of motor or direct driven robots, servo and hydraulic actuators, modbus control and the first industrial Robot introduced whilst star wars was on the TV and the internet a brand new innovation. During the 1980's the internet developed along with it control systems such as Asibus, Canbus, and networked systems which in turn brought about computer controlled robots. In the 1990s, industrial robots were already advanced mechatronic systems, synergistically integrating mechanical design, electronics, software, and control, but with no real awareness of what was happening around them. Typical operations that automation and Robotics were carry out were welding and assembly in the automotive sector, material handling in warehousing and manufacturing operations and packing and palletisation in the food industry. There were automated production lines where robots seemed to work together, but this was not quite true. Each robot was actually an isolated manufacturing cell with a specific manufacturing task, whereas the cells were connected to the rest of the process by conveyor systems for work piece handling. Even in cases where several robot arms worked together on one work piece (like in car assembly lines), those robots were not programmed independently but as one machine with predefined movements. The lack of awareness, and hence the inability of those robots to vary their behaviour in an autonomous way, implied strong constraints to guarantee safety (Grau, et al., 2020).

The 2000s were characterized by the first approaches allowing robots and human operators to partially share the same spaces, mainly through supervision solutions including the prediction of human behaviour and the use of proper sensor systems. In that period, the necessity of opening the cages in which the robots were enclosed to allow some initial form of human–robot collaboration was also addressed by the international ISO 10218 safety standards. In recent years, collaborative robots (cobots) are becoming part of the most advanced manufacturing plants to guarantee not only high levels of safety but also flexibility in production. The introduction of cobots represents a

significant pillar of robotics in the Industry 4.0 scenario, which is going to deeply change the manufacturing and production processes. Robots and humans working in the same space is now a normal operation in the 2000's with Robot payloads now even working in excess of 1000kg's the variety of tasks that can be carried out is almost endless. WLAN, Bluetooth and 4G connectivity is now commonly used and Robots and automation has expanded across many sector including surgical application and Robots in space.

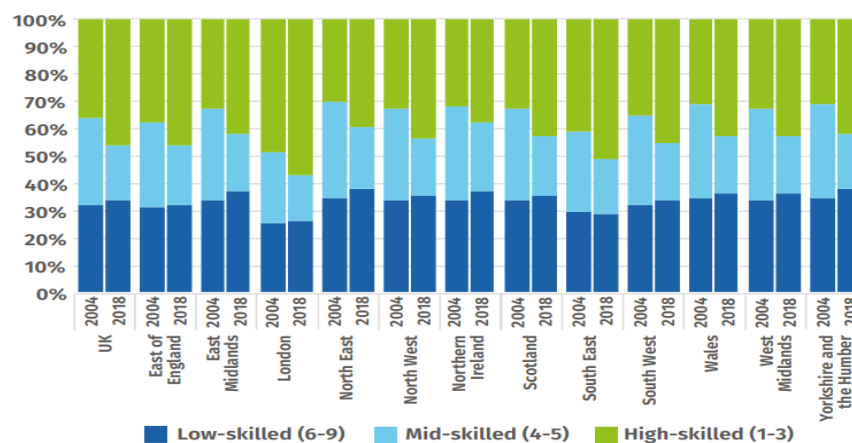


(Grau, et al., 2020)

4.2-Automation in Wales

Wales is at the centre of a number of significant disruptions likely to bring long-term changes for its people and economy and automation is likely to have a significant impact over the coming years. Previous IPPR research has shown that 46.4 % of jobs in Wales have high potential for change through automation. Across the UK, accommodation and food services, as well as wholesale, retail, and repair of vehicles have the highest proportion of jobs with high potential for change through automation at 65 per cent and 64 per cent respectively (Fawcett & Russell, 2019).

Percentage change in proportion of all jobs at different skill levels from October 2004–September 2005 and October 2017–September 2018 across the UK



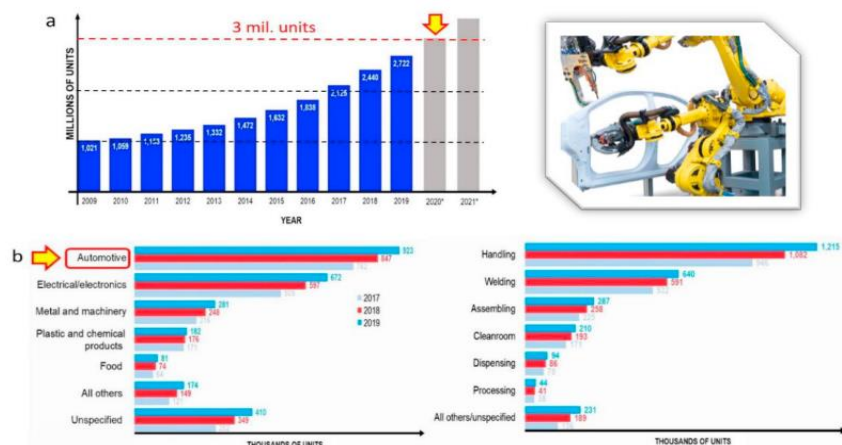
(Fawcett & Russell, 2019).

Wales has a proud industrial history built around in heavy industry such as coal, steel and manufacturing. The first million pound deal was made in Cardiff at the coal exchange and Swansea was known as the copper capital of the world. As the economy changed multinational companies such as Fords, Sony, Panasonic, LG, Airbus and General electrics arrived in Wales and along with it Automation and Robotics evolved. The development these industries requiring mass production, created huge investment in new infrastructure, including road networks and led to large numbers being employed in factories carrying out low-skilled production roles on semi-automated assembly lines. Today, things including the extensive use of robots in car plants and the potential for autonomous vehicles to eliminate the need for people to move products around are more readily seen (Brown, 2019). Wales has been at the forefront of innovation but as the multinational companies pack and leave wales it does leave the country in a precarious position. Digital innovation is a game changer. Economies, whether large or small, developed or emerging, have to confront major challenges to establish new business models, employment practices, and ways of skilling their workforce. Wales must now take similar action or be left behind in a changing world (Brown, 2019). The key critical target for manufacturers in wales has to be to invest in training and upskilling. Government reports indicate that within the next 10 years half of jobs could be automated which looking back at point 4.1 and how quickly technology changed over a decade this figure could be more than achievable. Perhaps this is a dream for ambitions engineers and technicians who embrace innovative change but worrying time for the unskilled and companies that are not willing to invest in upskilling.

4.3-Automation in Manufacturing

Robotics and automation adoption within the UK manufacturing sector is increasing but is still behind other countries (see appendices 10.1). The International Federation of Robotics measures robot density, the number of robots per 10,000 employees in manufacturing industry. The UK currently ranks 24th on this table with a robot density of 111 which is below the world average (Linkedin, 2023). It could be argued that a reason for this is the lack of capital investment and a reluctance to upskill workers along with a history of low wages as explained in point 2.4. This is particularly prominent in unskilled, repetitive task manufacturing and something the author's personally experienced in food and plastic manufacturing.

The automotive and electronics sectors have been vocal in communicating how they are leading the way regarding growth in automation and robotics. The automotive sector alone communicates that in 2019 with 33% of total supply of robots were into that sector (Bartos, et al., 2021). This sector has been the major market for robotics worldwide and has largely driven the development of robot technology. The relatively high volumes of this sector, together with the need for flexibility to handle different model variants, is very suited to the capabilities of robots (Bartos, et al., 2021).



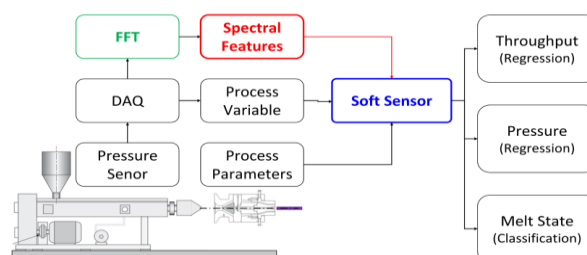
(Bartos, et al., 2021)

Food and drinks manufacturing is a big sector employing a lot of people in South Wales to the extent of when combined, more than both automotive and aerospace combined. The high labour levels was likely to be driven in the past by low wage cost for unskilled task such packing and stacking along with high costs of automation but the threats of forecasted investment into automation and Robotics is now coming to fruition. In recent years adoption has increased but there is still the opportunity for significant growth.

4.4-Automation in the sector

The principles of extrusion and Mechanical design remain relatively unchanged since scale up into manufacturing lines. 3.2 and 3.3 detailed technology in extrusion as a sector but there are gaps the author has physically seen based on 10 years of experience in extrusion.

Extrusion is an old technology and in a lot of cases the original OEM don't exist anymore. An extruder in itself consist of a heated screw and barrel that melts polymer beads into a molten material with the heap of heat generated through mechanical shear. Depending on product type a die is used to shape the profile to obtain the end product. From the molten form is cooled to solidify it and the converted and cut at the end of the process. Most extrusion equipment is not production recorded and not integrated to provide manufacturing information. Some production lines do not even have sensors installed to monitor basic signals. This will cause the production lines to manufacture outside of efficient parameters and in optimal mode along with making it very difficult to troubleshoot when exceptions occur (Wang, 2023). As explained in 3.1 because the basic principles of extrusion have remained the same and data acquisition is now ahead of the industry's ability to use it questions will be asked about value for money of investment. There is a place for artificial intelligence, but as materials will remain the biggest cost factor, it can only nibble at reducing manufacturing cost (Griff, 2021). For the plastic extrusion sector as a whole the main opportunity for automation is focussed on smart sensors allowing better processing of recycled plastic pellets (RPP) and bio degradable polymers. Melt pressure and temperature sensor, Melt flow indicators, Viscometers and smarter PID controllers providing real time data and data collection will all be required as the industry moves away from Virgin plastics to Recycled and Bio polymers.



(Wang, 2023)

End of line automation tends to be bespoke and that's seen between Berry plants. Within Tubex the end of line process applications is the part of the process where Automation and robotics take over. The authors experience from working in the extrusion and food industry indicates that it's not uncommon to find the base automation and robotics to be off the shelf equipment but bespoke

modification added due to patents and NDA's of specialised products. Omron, Kuka, ABB or Fanuc may have supplied off the shelf Robots or handling equipment but specialist end effectors, cutting devices, material handling or spray mechanisms may be required from independent integrators or internal project teams. Staying ahead of the competition is critical so allowing OEMS access to all specialist parts of the process when they install there equipment that can then be shared with competitors is something that needs to be tightly controlled. If OEMS are having to visit site to fault find or modify equipment its not uncommon for the patented aspects to be removed prior to their visit. If automation and Robotic solution are shared with competitors then it can lead to the competitors copying products, undercutting prices or even improvements into competitors' products.

4.5-A look into independent integrators

There are many integrators in the UK that will provide Robotics and Automation solution using Robots such as ABB, KUKA, Universal Robots and Boston Dynamics to mention just a few. DHL,BP, Jaguar land rover, Fords are all heavily invested into robotics with even Western Power now communicating they are using Robotics and automation. With the level now seen its no surprise that many independent integrators are available in the Wales are and even more so it you extend the area to South wales and the west of England. A lot of these independent integrators the author has collaborated with hold accreditation as approved suppliers from the Robot OEMS and in general have an established business in automation. SP Technology, Loop technology, applied automation and activ8 robotics are just a few companies that have provided automation to Berry plants to help with the bespoke solutions not provided by the OEM's.

4.6-Innovation support

With Tata, Fords, LG, Sony and Panasonic having a heavy presence in South Wales in the past there is no shortage of support in the area to help with innovation support. Experience suggests to cement a future then investment into training is essential. Its things such as dedicated training centres or workshops along with colleges and universities that will help support the foundation of innovation in Wales.

Quantative surveys (appendices 10.2) indicated useful insights that engineers, technicians and setters are daunted by the thought of robotics and advanced automation. Mechanical aptitude and understanding of how to fix machines when they break down did not transpire into the thought of Robotics learning. One of the most important skills required for many robotics jobs is a mechanical aptitude. This includes an understanding of how machines work and being able to fix them when

they break down because robots are, at their core, machines. They are made up of moving parts that need to be maintained and repaired when they break (career, 2022). In reality engineers and technicians with experience of mechanical and electrical systems have a skill that is transferable to robotics. For machine setters with a hands on background or who have ever spent time repairing a car or even repairing an appliance at home then this is a good grounding for working with Robotics and automation.

Writing machine code has always been something lots of engineers have struggled with but is an essential part of Robotics and automation. It may be a PLC programme, Setting of a variable speed drive or software for a servo all of which generally require as a minimum some on line learning, OEM support or at best a training course. Training courses exist at all sort of levels from integrator awareness training, skills training centres or training through a higher education college or university. Higher education institutions look to future industry needs and is critically important to invest in engineers of the future as much as current engineers. The gap between the industry's needs and competencies offered generally by education is revealing the increasing need to find new educational models to face the future (Tan, et al., 2019). A quantitative study carried out in Liverpool highlighted the four main issues that are important in preparing students for future industry which are the characteristics of future workforce, students' readiness to work, expectations on different roles played at the tertiary education level and awareness of the latest trends. Everyone's expectation are different and hence, institutions, employers and students have to also readjust their expectations towards each other's role (Tan, et al., 2019). To Challenge this statement the author believes that collaboration between higher education establishments and industry has to be more aligned. For examples if universities understand the industry sectors they are located geographically then trainings can be tailored for the industry. A great example of this is GE aviation Wales which in conjunction with College Y Cymoedd have collaborated for many years to develop bespoke aviation training. In 2023 the Minister for Economy Vaughan Gethin MS joined the team from GE Aerospace Wales to mark the official opening of the new Training Academy at the site in Nantgarw (Gregory, 2023). With over 400 applicants for apprenticeships every year along with a substantial amount of workplace training GE has a blue print focussed on innovation. Similar collaborations are in place with other higher education facilities and large organisation such as Tata steel and Fords engine plant.

5- Automation Robotics

5.1Automation and Robotics OEM's in Berry

As a customer first organisation, delivering over 100,000 solutions around the world, innovation is core to what Berry's. With a continuous improvement culture and material science expertise opportunities are created to bring new ideas for customers in each business challenge taken on. Customer insights and merged with Berry strengths in design expertise and leading capabilities to simplify or deliver on the needs of the markets and brands served (Berry, 2023). With this innovation mind-set and expectation from customers in each sector Automation and Robotics is a hot topic with plant leaders and business excellence teams. Collaboration between the groups is also encouraged to share best practices but as a company with over 250 facility's worldwide there is a lot of varied technologies. Standardisation through Berry is key and OEMs such as Reifenhäuser, Acceli and Mondon have provided innovative machines in collaboration with Berry to automate and improve processes.

Reifenhäuser

Reifenhäuser Reicofil is a specialist and leading global manufacturer of complete spunbond, meltblown, and composite lines which meet the highest quality requirements in hygiene, medicine, and filtration. (Reifenhäuser, 2023). Since the 1950s Reifenhäuser has become one of the most important machine manufacturing companies of the global plastics industry with they're technology a milestone in the production of plastics throughout the world. This technology includes blown film, non-wovens, and wood-polymer composites (Plastics, n.d.). Within Berry's European plants Reifenhäuser has a very strong presence and collaborative relationship.

Acceli

A.Celli Nonwovens, a current leader in its market, has been manufacturing nonwovens machinery for over 75 years. The Italian company offers a comprehensive range of Winders & Slitter-Rewinders featuring state-of-the-art solutions customised to spunbond, spunmelt, spunlace and nonwovens roll goods production with a special focus on lightweight fabrics and high-speed production. A.Celli also offers a reel data tracking and archiving system, which allows customers to keep the detailed history of the product which is key in Healthcare applications. Collaborating with Acceli, Berry Global has created a Centre of Excellence for carded nonwovens with a key focus on innovation. Establishing a

pilot line and dedicated laboratory to support customers in the development of enhanced functionality such as softness and sustainability (Morgantini, 2018).

Mondon

Mondon has been designing and manufacturing converting machines for four decades and the company offers equipment for the hygiene, healthcare, automotive and construction sectors. Its portfolio includes un-winders, slitter re-winders, turret winders and spooling lines in several formats. Mondon equipment can be integrated into existing lines by adapting the design meaning they can be found in multiple Berry site albeit in different size profiles.

All of the above OEM's provide their own innovative solutions that when installed as part of a manufacturing process merge to form a line that has proven to provide industry leading products whilst maintaining high and reliable output. Results such as this has not been an overnight win but has taken many years of Berry investments whilst maintain strong relationships with the OEM's to innovate and strive to always improve. Such collaborations with OEM's are not uncommon with fords and Fanuc being a great example. Fanuc USA have been providing Robots to Ford for many years and that relationship has now moved across the Atlantic into Europe where by Fanuc has received a major order to supply the Cologne plant of Ford with around 500 robots to assist in the construction of electric car bodies (Automation, 2021).

5.2 Automation and robotics case study in Berry

Lean manufacturing is a target for most manufacturers but there is always the financial aspect that requires quantifying and that can highlight that a cost change to a process may outweigh the benefit. There may also be NDA's in place or bespoke technology being use that makes it difficult to work with OEM's to provide improvements or full solutions. It is quite common within Berry that site or division's wok closely and in collaboration with OEMs to invent and install improvements components so costs are kept down and on occasions the equipment under NDA's kept secretive.

Berry and Reifenhauer worked on one such collaboration on a project to reduce change over times in extrusion. Change overs have to happen so when they do how do they be made to be as efficient as possible. Every product change on the thermoforming line felt like a strenuous hike except that there was no reward on arrival at the peak. The cause was the installed bolt coextrusion adapter.

Whenever a new product was changed, plant operators had to fiddle around for a long time to adjust the layer distribution for the new product but in the end, they had to accept high tolerances.

Experiments to influence the flow of layers using different materials and process parameters failed or had only a marginal influence. Only a ReicoFeed Pro IE co-extrusion adapter from Reifenhäuser promised the desired combination of pinpoint layer distribution, high flexibility, and changeover speed. Production employees and technicians at the Berry Superfos location were quickly convinced of the Reifenhäuser solution. Test results confirmed the improvements expected from the system and, incidentally, provided concrete data to calculate a sound business case. One of the special challenges on the path to optimizing layer distribution was the feed block and integrating into an existing line. However, a co-extrusion adapter requires certain feed geometries. Reifenhäuser designed the entire melt line and Berry took over the actual installation of the adapter. After one week the necessary learnings on how the system interacts with materials was understood. (New Co extrusion adapter for Berry, 2021).

5.3 Automating the missing 11%

Unfortunately the area in question at Berry's Tubex plant is not an area that the above OEM's in section 5 can help us with as its outside their expertise so automating the missing 11% is likely to mean bespoke innovative solutions. What can help though is the Berry group and as with such a vast range of products Collaborating with the group has led to introductions to Robotic and Automation providers. Berry Tarragona and Cuijk have over the years faced similar projects where by solutions were bespoke and unknown so have fostered a relationship with KUKA Robotics.

With conversion of Tubex's finished goods being bespoke there has always been several factors that have stopped the investment. No off the shelf solutions and no known designs being a big factor along with the cost of automation and Robotics. Section 4 discussed the impact of rising raw materials and labour costs driven by minimum wage which has had the impact of looking how rising cost can be offset. The following sections addresses areas that need to be considered when implementing Robotics and Automation at site.

6- Implementation

6.1-The manufacturing facility- where we are at now

Manufacturing processes have evolved greatly over the past few decades, and one of the most significant changes has been the introduction of automation. Automated systems in manufacturing have revolutionised the way products are made, and they have made the process faster, more efficient, and more accurate (Knight, n.d.). Berry's Tubex plant only partially took on board the automation philosophy and changes have only occurred whilst under corporate ownership. Whilst privately owned the company was predominately run by directors with a mechanical engineering background and control systems were basic where by most moving parts were controlled by pneumatic logic. The advantages of this system is, low-cost, high reliability, and long life of pneumatic system and it is widely used in machinery and automatic control (Liu & Sun, 2021). The problem with this type of system is fault finding is very difficult and there can be safety implications when things fail.

Under Corporate ownership Tubex had the opportunity to start investing in areas that were failing and downtime due to machine failures was highlighted in the top 3 improvement areas. Collaboration with finance teams allowed business cases to be developed providing data evidence on the failures. It also ensured any opportunity for rebates into any innovation followed government guidelines whereby capital allowances for plant and machinery are declared on Company Tax returns (HMRC, 2022). Capital expenditure was released to start machine upgrades and engineering teams brainstormed on what solutions were required and what steps could be undertaken. Budgets available had limitations so improvements would need to be broken down into steps and moving to PLC control systems predicted big benefits. With PLC's widely used in industrial automation systems to control machines and processes they offer a number of advantages over traditional relay-based or logic control systems, (automation, 2023). Its common knowledge that PLC's are widely used in control systems so there was little risk in moving from the theory to the physical.

With the pilot lines proven the automation of moving to PLC control was rolled out across all lines and Uptime immediately improved. The plant was now a lot more reliable but still a semi-automated process that requires a lot of labour to produce the end product. Reliable equipment also highlighted the inefficiency of labour attendance as previously machine downtime could be hidden in the data collection as lines would be stopped for staff sickness so if that line was un-serviceable due to an engineering fail it would show up as no labour masking inefficiency.

Investment into Automation has continued but the scope has always had to be semi automation as the solution into fully automating has no known solutions and will be totally bespoke. Integrators in the past have also declined the challenge to find solutions to automate. The application is quite simple for a human where by an operator has to insert a tie into a hold that's pre made in a plastic tube. The problem is dexterity, so for a robot to undertake the task it will challenge its ability to deal with complex movements. The robot will be required to replicate a human hand and move in many directions in a very quick cycle time. Solutions that may be found today regarding Robotics may not be the solutions of the future with bespoke surgical robots or evaluating them for fitness to a task gaining attention. Common metrics that characterize a manipulator's performance are workspace reachability and dexterity considering actuator limits and potentially collisions with the environment (Leibbrandt, et al., 2023). These kinds of studies could filter down into manufacturing in years' time and change the face of manufacturing further.

6.2-Research

As with many co-corporate companies lean six sigma (LSS) is used to improve manufacturing efficiencies and with that many tools are taught that supports innovation projects. Lean six sigma is a well-structured process improvement methodology aimed at removing wastes and defects to increase the operational efficiency of a process. As far as an application framework is concerned, define, measure, analyse, improve, control (DMAIC) is the most widely used (Krishnan, et al., 2022).

Using lean Six Sigma methods for project management provides many of the key milestones required in planning a project. The first step in a Six Sigma project is to define the problems and the desired outcomes of the project. This step requires much of the same attention to detail in regard to the planning of the project that is seen in the initiating and planning phases. In the define phase, the use of a project charter, SIPOC, FMEA, and many other tools gives visibility to things like project goals, key stakeholders, and possible areas for failure (Parker, n.d.). Defining the project correctly can have a big impact on the project a project charter allows a scope to be put together identifying the problem or opportunity statement, justification, project ownership along with high level financial benefits and timings, all of which require research on each topic. The DMAIC process will be followed through the whole project where more in depth measurement and Analysis will take place prior to any improvements taking place. The project charter will also ask questions of potential stakeholders both internal and external whereby integrator selection for this type of project will be key.

6.2.1-Integrator selection

Choosing the right system integrator is a critical decision that can significantly impact the success of a project. Using integrators that have been used in the past or worked within the same company is a good screening process or utilising integrators that have been recommended by OEMs. Reducing risk and giving the project the highest chance of success is the desired outcome and there are some key recommendations to follow.

- 1) Expertise and Experience- Evaluate the integrators expertise in the specific technology or industry relevant to the project. Consider their track record of successful projects and the complexity of projects they have handled. Check if they have experience working with organizations of similar size and requirements.
- 2) Technical Proficiency, References and Portfolio- Assess the technical skills and certifications of their team members who will be working on the project. Ensure that they have a deep understanding of the technologies, platforms, and systems. Request references from past clients and inquire about their experiences working with the integrator.
- 3) Project Management Approach- Understand the integrator's project management methodology. Clarify roles and responsibilities, communication channels, and the project timeline.
- 4) Scalability, support, Collaboration and Communication- Choose an integrator that can design solutions that are scalable and adaptable to organisation future needs. Ensure the integrator offers adequate post-implementation support, including troubleshooting, bug fixes, updates, and maintenance. How do they handle future upgrades, expansions, or integrations and how do they communicate.

Using OEM recommended integrators and integrators that have working in Berry sites along with evaluating the integrators enables informed decision to be made that align with project goals. (Trinitium, 2023).

6.2.2-Challenges (Tie Sorting, Tie insertion, nesting of products)

Identifying what can or can't be automated within manufacturing is not that simple with a lot of engineers misunderstanding the limitations of automation. There is the argument that anything can be automated but that comes at a price and return on investment is key along with health and safety considerations. As defined in the Authors project charter 3 key points have been identified that are critical to the process:

Criteria 1- Cable ties that are decanted from box will need to be sorted so they are all the correct way around so they can be handles by any Robot or Automation.

Criteria 2- Cable ties must be automatically into holes of the finish produced and sipped up to the required set point.

Criteria 3- The Finished product complete with Cable tie must be automatically transferred to a tote bin (in house this is called nesting).

Each criteria has a known solutions in other applications so base ideas for the robots or automation can be developed form these.

Criteria 1- cap bowl feeder

One of the main disadvantages with Automation is difficulty in achieving flexibility within the process in terms of shifting batch production from one process to another. If production can be improved through flexibility then the cost of automation should be recouped. Using an operator to sort and stack cable ties in the right orientation would be near impossible to hit line cycle times. Conventional vibratory bowl feeders employed to present parts to manufacturing lines in the correct orientation are commonly used (Maher, 2010). This is stock item with proven concepts for other applications such as cap sorters (below Picture)



(Reeco, n.d.)

Criteria 2- cable tie gun (bravo, 1986)

Cable ties are commonly used in the packaging industry, for example to seal bags, secure an item to a support, bundle objects together or for security purposes. Their low production cost and ease of use has led to cable ties having many domestic and industrial applications, not limited to electrical cable management. The rigid design of the traditional cable tie is intended to prevent any expansion or flexing of secured objects, however this can cause issues when supporting or displaying fragile products, such as plants or compressible tubing (Qureshi, 2016). It is in the application of Tubing where the cable ties are used in the Tubex product to fix the end product to wooden stakes at the customer's sites. The expectation of the customer is that the finished product arrives with the cable tie pre inserted in the product to a set length for ease of installation.

In the Cable Harness Design and Assembly System, cables are designed at a CAD workstation and the cable harness is built by a remote robot.

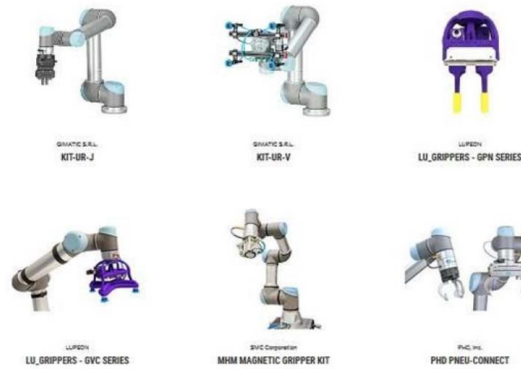


(Hellermann, n.d.)

Criteria 3-Robot end effector

Almost all Robotics require bespoke accessories to carry out the task its being asked to do and the end effector is one of those complex accessories. In recent trade shows attended, many different types of end effectors could be seen and whilst many of them were attached to Robotics that were carrying out similar tasks their make-up was vastly different. Without an end effector, most robots are practically useless. An articulated robotic arm can be programmed to a particular location within its workspace, but without some sort of end effector, it has no way to perform any operation (Automate, 2019). There are three common types of end effectors comprising of grippers, process tolls and sensors but it's the grippers that would be required in this manufacturing projects (Below Picture). Automating the missing 11% requires a solution similar to that of a packing application with the addition of very accurate locating devices whilst being dexterous.

The past decade has witnessed a vast growth of intelligent robotic solutions for manufacturing packing applications. completion of many tasks still rely on human labour in particular tightly packing products that are picked from an unstructured pile still remains manual. This demands high levels of accuracy from the perception component as well as the manipulation strategy. Indeed, surprisingly little prior work seems to exist that explicitly addresses this problem, let alone using a simple, suction-based end-effector (Shome, 2019). The authors missing 11% extends this complexity further as the cable ties requires sorting into structures piles prior to being manipulated through small holes, looped around then tethered together all within a high speed cycle time. Image and sensing technology will play a big part in supporting the manipulator along with high speed processors. The Authors experience gained in working with Automation suggests that electrical and control systems for this application will not be too much of an issue but the mechanical aspect of designing and selecting of the manipulator is where the R and D will become complex.



(Universal, 2019)

6.2.3-Technical specification and performance

Technical specifications and real life performance targets must be set out as part of any user specification requirements (URS). There will also be ISO standards that are required to be met but they will be covered in detail by QEHS managers and not discussed in this report. A URS is an extremely important technical document that is generated and used to initiate the tender process when a client is looking to purchase new capital equipment to automate a production operation. The document is specifically created as a place where the machine deliverables are recorded, whether they are a necessity or simply a nice to have (Robotics, 2018). It's crucially important that a URS is written clearly and concisely and that it is agreed by both the potential supplier and the end user so that both parties know what machine performance needs to be achieved. Failure to produce a User Requirement Specification could result in wasted time rewriting documentation, offering the wrong automated solution or, in the worst instance, providing equipment which is not suitable for the process. The above statement is off an integrator who I've worked with on previous projects and have in fact built a machine for a Berry site based on an incorrect URS which was detrimental to the success of a project. A good URS would comprise of:

- 1) A Good summary providing an in depth description of the proposed task
- 2) A validation plan
- 3) Involvement from staff working at the manufacturing line
- 4) Supporting documentation including supplier preferences, technical specifications, cable colouring, software packages etc.

The URS for the topic of collaborative robots in an environment of unskilled workforce needs to be closely specified. Conventional robotic technology has been designed with highly trained users in

mind. As robots achieve higher levels of autonomy in a variety of environments, robot designers can no longer assume a high level of expertise from all potential users, and instead they must create human robot interfaces that enable simple and effective communication between robots and untrained users (Blidaru, et al., 2018). With solutions to the missing 11% not yet final, building a URS based on collaborative Robots will have to be discussed prior to proof of concepts being completed.

The early stages of engineering design will heavily include suggestions on the materials to be used, general design, technical standard and a function block diagram. The given solutions from different providers may look widely different but the core components must remain the same. For example if the control was stated in the URS as having to be as Siemens or the pneumatics as Festo then they should remain in the final design solution. Likewise if changeover times or cycle's times have been stated then they should be adhered too.

6.2.4-Ethics and training

When you engage a new technology initiative, there's often concern about the learning curve for users (Worksoft, n.d.). On the other end of the spectrum there is also the concern over automation and robotics taking over from humans in manufacturing. The fear of job loss and unemployment is a valid concern, as automation has the potential to replace certain roles entirely. This can lead to economic inequality and social unrest if not managed properly. It is essential to ensure that the benefits of automation are shared equitably and that workers are provided with opportunities for retraining and upskilling to adapt to changing job requirements (Martino, 2023). The Authors titled this report as the missing 11% derived from year on year data of production inefficiency due to the unavailability of labour. Ethically there is limited risk in job losses when introducing this automation but that will only apply to permanent staff. Temporary labour will be impacted due to the fact that extra staff won't be required when Automation is in place. Quantifying this will be difficult as there is no guarantee of how many hours temporary labour will be required to work year on year.

The authors own personal and professional development experience identifies that training is essential but not always offered by employees. Budgets are not always in place to provide adequate training and in non-technical tasks employers may not see the full impact but when it comes to automation non investment in training will impact the project success and equipment efficiency.

6.2.5-Cycle by cycle performance- Repeatable process, rejections, QC, FMEA

A fully automated production line whereby equipment and systems that complete all or part of the process with machines and virtually little to no human intervention is the goal. In a fully automated production environment, employee involvement is typically limited to loading product recipes into

the machine interface before supervising and monitoring the system for issues, such as part replenishment that requires loading product components into the respective feed systems (Automation, n.d.). This is the vision of most manufacturers as Labour costs make up one of the biggest costs when manufacturing products and is certainly evident in low value goods.

An automation case study reviewed on a high-tech manufacturer operating in a high-cost country delivering safety products discusses experiences from a concurrent product and automated assembly process development in manufacturing. (Roulet-Dubonnet, et al., 2018). The paper suggests automated assembly is a key factor to develop a competitive manufacturing system in high-cost countries, to reduce unit cost, reduce rework and increase product quality. However, for a medium sized manufacturing company with limited resources, optimizing the product design to automated assembly and developing the automated assembly line is often a challenging task. The author has experienced alignment with that statement with real life experience of how challenging automating can be. Design for assembly or design for manufacturing provides methods that can definitely support building an automated production line. Using the design methods helps to provide guidance on the process itself, the success rate expectations on repeatability, limitations on rejects or scrap and apply thoughts on how quality control (QC) can be implemented into the automation. When all of the above topics have solutions that collaborate with each other then cycle by cycle performance should be achieved. Experiences gained from the authors past innovation projects implies that project scope must remain live as design changes from original scope is almost certain when the limits of design and engineering are being pushed to the maximum. Evidence of this is seen through history from Thomas Edison and the light bulb to Brunel's Clifton suspension bridge, both of which pushed limits and designs changed for successful innovations.

6.3-Proposed line assembly plan

The proposed line assembly is subject to change based of integrators solution but as with any innovation an idea on where we want to be and base schematic layout drawing at a high level can give representation of the end goal (Appendices 10.3). Industry 4.0 offers many platforms that can support layout planning from basic 2D drawings to digital twins.

Optimising assembly lines may sound like a straightforward solution but with the production lines being the backbone of many manufacturing processes they pose challenges and opportunities for efficiency and safety. Some key steps to follow prior to using platforms such as digital twins are:

- Analyse your process flow- and identify the inputs, outputs, and activities of each stage. You can use tools like value stream mapping, spaghetti diagrams, or process flowcharts to

visualise and document your process. This will help you to spot bottlenecks, redundancies, delays, and wastes that affect your efficiency and safety.

- Apply lean principles- to reduce the wastes and inefficiencies identified in your process analysis. Lean principles focus on maximizing value for customers and minimizing waste for producers. When designing your assembly line layout, you can use pull, flow, tact, and workstation principles.
- Implement 5S- methodology that helps you to organise, clean, and standardize your workspace. 5S stands for sorting, setting in order, shining, standardizing, and sustaining (manufacturing, 2024).

In Industry 4.0, smart manufacturing has become a development direction of the world's manufacturing industry. Digital twins (DT) technology is a modern smart manufacturing solution (SMS). Nowadays, the digital twin trend is gaining momentum because of rapidly evolving simulation and modelling capabilities, better interoperability and IoT sensors, and more availability of tools and computing infrastructure (Leng, et al., 2021). Use of DT to create a proposed line layout that include automation and technology along with cycle time estimations provides clarity to designers, engineers and also those that who may struggle to visualise the end goal. Automation and robots performing complex tasks, sensors for monitoring conditions and parameters, software for managing production planning, scheduling, inventory, quality, and maintenance, as well as IoT devices can all be run in simulation on DT packages.

7- Concepts

I4.0 is a trending concept in itself which promises remarkable results for industries while profoundly changing organisations in many terms. Changes start in the way of setting up business models through the whole production process until the final point when the customer receives the product. However, considering that I4.0 is a newly emerging concept owning a wide range of definitions, there is still a lack of knowledge in concrete steps and only a few scenarios to follow to shift to I4.0 (Suleiman, et al., 2022). Finding concepts of mechanical, process and electrical solutions aligned with industry 4.0 is the aim to solve the missing 11% with all solutions having longevity with technology. The mantra of just because it's always been done that way doesn't make it the right way means a lot in any innovation project.

7.1-Solutions-mechanical-Industry 4.0 mechanical components

Even with the digital world moving incredibly fast and process and control becoming the brains behind machine function, mechanical movement will always serve a purpose in machine build and manufacturing lines. Traditional engineering process and mechanical engineering continues to adapt and evolve with industry 4.0. Many people assume the introduction of emerging technologies such as AI, automation, and machine learning will have a negative impact on traditional engineering roles. However, the need for engineering innovation isn't slowing down. Mechanical Engineers looking to the future would benefit from a good understanding of the new technologies associated with Industry 4.0, as it is increasingly adopted across the sector. As more companies adopt these technologies there will also be opportunities for employees to upskill and advance their careers. (Engtal, 2021).

Mechanical engineering has always been the foundation of industrial activity, while information technology, the essential part of Industry 4.0, is its main source of innovation (Hamrol, et al., 2019). Product design and product properties are usually manufactured according to a specific technology. For example designers may design components depending on the type of milling machine or lathe they have available to them which may limit product design. Combining IT to mechanical design presents opportunities to use processes such as advanced CNC, intelligent tools and measurement devices and additive manufacturing. These topics will be discussed in 7.4.

Moving products around and presentation to automation is an operation that can be detrimental to productivity, quality and output if designed wrong. One of the most fundamental parts of manufacturing automation is often linear motion and in the missing 11 % this could include moving ties around, Tubes around or even the machine or robotic actuators themselves. Smart actuators

and sensor can be fitted to mechanical operations to reduce cycles, reduce loading and reduce maintenance and failures. Integration of microelectronics ensures mechanical components play a key part in industry 4.0 whilst mechanical engineers must be able to respond where humans and machines unite to be ready for new possibilities, and harness the potential of digital technology. Mechanical engineering disciplines must be able to solve complex problems in industry, theoretical concepts of natural science, application of engineering mathematics, special and unique materials science, theoretical principles of engineering design, production, renewable energy, energy conversion, or industrial mechatronics/automation (Industry 4.0: Challenges of Mechanical Engineering for , 2021). Mechanical components will always be the backbone to most innovations whilst combining Physics, engineering maths and material science to solutions.

7.2-Solutions electrical- Industry 4.0 electrical

As part of the author's research into the missing 11%, electrical solutions that are deemed to make a big impact into concept include sensors, relays and cabling. Electrical energy has been used as a primary energy source since the beginning of the 20th century and with the creation of electronic devices automated machines grew in stature, resulting in reduced effort, improved speed, improved precision, and, in some circumstances, complete replacement of the human with sensors playing an essential role in production for years (Javaid, et al., 2021).

Smart sensors are used to monitor different industrial processes, collecting data, taking measurement, and sending the data to centralized cloud computing platforms where information is collected and analysed for patterns. This data can be monitored by key decision makers at any time. Three types of smart sensors that may be requires in the authors solution include:

- Temperature sensors-Temperature sensors will be require to ensure the plastic product is not subjected to too much heat and when connected to a smart controller its not limited to just turning the controller on and off but can be connected to a cloud computing platform for data collection.
- Pressure sensors- within extrusion are used to ensure machine safety is achieved by monitoring the amount of backpressure being created and can knock machine off in times of danger and alert a centralised computing.
- Proximity sensors- are used in to detect product location and track crowd flow. Once a proximity sensor detects a product in place it will initiate a signal to start or stop a process. (rgbsi, n.d.).

Sensors can adapt to the various applications with manufacturers making constant progress in sensor precision, reliability, response times, robustness, miniaturisation, communications and efficiencies with the spread of sophisticated electronic control system. (Javaid, et al., 2021).

Electrical motors are another piece of equipment that are common across many industries and the likelihood is any solution requiring material movement will have a motor included in the design.

Fault Detection and Diagnosis (FDD) of their elements represent a first fundamental step for the development in the future of predictive maintenance algorithms at plant level. (Pris, et al., 2020).

The principle behind electrical motors is to use electrical energy and convert it into rotational energy or movements. The AC motor takes electrical power from the voltage supply system and converts it into mechanical power in the form of speed and torque. However losses occur in AC motors, which is unavoidable whenever energy is converted the effects are copper losses, bar losses Iron losses and friction losses (Eurodrive, 2024). It is these losses that result in component failure especially when friction in the bearings, the copper and the rod causes the motor to heat up. Amalgamation of these electrical components with industry 4.0 technology to first select the correct motor and secondly monitor the motor or using industry 4.0 algorithms will help create robust systems.

,

7.3-Solutions-Process control- Control systems, AI, etc.

Process control and big data collection has endless opportunities with industry and when I4.0 combined with the availability to simulate applications using digital twins then process solutions can be proven prior to implementation. The digital twin is a digital representation of a physical object, person, or process, contextualised in a digital version of an environment. Digital twins can help simulate real situations and their outcomes, ultimately allowing companies make better decisions (McKinsey, 2023).

Smart process controllers use a frame work that has four main modules comprising of control and awareness, process diagnostics, prognosis and external interaction (Cohen & Singer, 2021) which interact with local sensor and frameworks enable them to communicate with other systems. Programmable Logic controllers (PLC) currently form an important technological basis for the automation of industrial processes and process control. Even in the age of industry 4.0 and industrial internet, it can be assumed that these controllers will continue to be required to a considerable extent for the production of tomorrow (Langmann & Michael, 2019) whilst evolving to meet the requirements of industry 4.0. The PLC's can offer solution that can be operated and programmed locally but under real time conditions but also as part of a supervisory control and data acquisition

(SCADA) platform for big data collection and analytics. The author's experience of working with PLC's at a time when pendant hand controllers were used to create ladder logic right through the networked SCADA and bus systems provides an argument that whatever the process a PLC solution is very robust and capable.

Incorporating the PLC to sensors and actuators provides the basis of a solution the author is looking to solve but a key consideration is vision systems. Machine Vision (MV), like other digital technologies is a critical component of Industry 4.0 and the removal of human error simultaneously minimises the probability of a mistake (Javaid, et al., 2022) when working with automation of repetitive high speed tasks, MV technology is critical in collecting the physical world and transferring it into networked, digital data where it may be evaluated and processed in real-time to raise operational efficiency, maintain quality standards, and reduce waste. In the author's solution MV would detect a registration mark on the finished product so the Robotics/ automation will then know exactly where that product is and can start the conversion process in the same point each time.

7.4 Trailing and iteration developments

Proof of concept can be the pathway from idea to product and help a designer or investor know if an idea is profitable (Justice & Codreanu, 2022) before laying out a large sum of cash. To start off a proof of concept a designer may focus on new features and test these extensively before implementing them with a prototype and sketches of model build.

A design engineer would then obtain off-the-shelf components and subcomponents to test that prototype function. The prototype looks and feels like a finished product, and even behaves like the product, but the prototype is built in a lab environment.

Both a proof of concept and a prototype are often mentioned among the most popular methods that help to determine if a product idea is viable and worth pursuing (Sanja, 2023) and industry 4.0 offers many platforms to support both. Formula 1 has experienced a real revolution in recent years due to the adoption of advanced rapid prototyping technologies and digital engineering, in which all modelling and evolution of the prototype is first done in a virtual way before becoming a physical model (Anna, 2021). The main advantages of making all the modifications of the project in the virtual model are the reduction of the cost and the saving of time to have a model in an advanced stage of development when compared to the traditional way of modelling and manufacturing. From the proven digital model additive manufacturing can then be introduced to create the prototype into a real physical component. Additive manufacturing has been around for more than 30 years but

recently the growth of additive manufacturing has been due to a constant development of the technologies and the ability to work with a wide range of materials. The basic principle of additive manufacturing consists of building 3D geometries by material addition layer by layer with one of the main advantages of additive manufacturing is being able to create geometric complexity that before could not be manufactured with traditional technologies (Pérez, et al., 2023). With the obvious advantage of cost reductions to produce prototype parts there is also a benefit in the time it takes to produce prototype parts and to make revised iterations. Rather than waiting on machine shops and tool makers to produce for example, aluminium components on a milling machine or lathe the parts can be 3D printed at a fraction of the cost and time. If another iteration is required then the modification can be made on a digital model and re printed rather than re-entering the tool room. Many items for the author's project solution may need to go through various iterations to find the most suitable profile so 3D printing will be very beneficial.

7.5-Training

It goes without question that any new equipment brought into any manufacturing site requires the correct level of training for end users. The health and safety executive (HSE) guidelines specify that all people using equipment at work must be adequately trained to ensure health and safety in its use, supervision or management. Some work activities require detailed formal training but, for most everyday activities involving work equipment, adequate training can be delivered in-house using the manufacturer's instructions and the background knowledge or skills of more experienced workers and managers (HSE, 2024). Work based training such as SOP help achieve consistency and familiarisation for operating a piece of equipment. These documented, step-by-step instructions for performing given tasks provide employees with everything they need to efficiently perform assignments without confusion, misinterpretation, or reinventing the proverbial wheel (Eisner, 2022). Sop's must be reviewed prior to they're approval for release and must be checked out and updated as necessitated over they're life cycle (Akyar, 2012). Unfortunately for technical staff it can be difficult to create SOP's that specify how to fault find or repair machinery but guidance can be given in user manuals listing known faults. This is common on OEM machines where more than one has been made previously. For new innovation projects then machine builder or designers are usually require to create a user manual to support fault find and provide some formal training to site staff.

The challenge for Tubex will be points highlighted in 4.2, 4.6 and 6.2.4 whereby investment into staff training is critical to successful implementation of an innovation project. There is already a technical skill gap at site due to year of little upskilling investment. Allocation of cash for training and internal

development plans have stalled since COVID and prior to that technical training was poor. In today's competitive and fast-changing world, the skills and capabilities of the workforce are vital to economic sustainability and growth. Yet, despite the central importance of skills development in the workplace, there has been a substantial and long-term decline in the volume of employer training and investment in training in the UK (Development, 2019).

This challenge should be an easy problem to fix as long as budgets are in place. South Wales has many training centres, universities, colleges and leading OEM's that can provide world class training. Technicians may find they're limits with Robotics and automation but investing in upskilling staff is certainly better than doing nothing at all even if some technical find they're level.

7.6-Strategy to implement

The chosen strategy for innovation at Tubex needs to be carefully considered due to the cultural reasons discussed in section 2. Additionally the existing workforce skillset and future training needs is the next step. Industry 4.0 innovation will not be able to make a significant difference if it is opposed by the organisation's existing workforce. Therefore, a change management strategy also needs to be defined, to allow a smooth transition from the traditional to the digital era.

A strategy following the lean six sigma DMAIC approach which is common within Berry sets out clear definitions of defining the project scope first using a project charter and data to define and measure the project. When it comes to the implementation phase change management is a key part of project success, and soliciting feedback during stakeholder interviews gives insight to the opinions of those impacted by the project. The team should review the original stakeholder analysis to determine how or if anything has changed, and what can be done to address those results. The results of the pilot run should also be compared to the scope and goals of the project (Butt, 2020). A pilot line is also the preferred method of introducing the innovative change also project management with clear communication is essential at all levels. Project management is the application of processes, methods, skills, knowledge and experience to achieve specific project objectives according to the project acceptance criteria within agreed parameters. Project management has final deliverables that are constrained to a finite timescale and budget (Dweck, 2019). Planning the timelines of the pilot line itself may will follow an individual plan using a Gant chart which set out milestones that need achieving. Each time a milestone is achieved communication to key stakeholders must be followed to keep every interested party updated on the project progress. This is very critical to stakeholders such as accounts along with management and project sponsors especially if release of capital is required at different stages of the project (see financial analysis for more detail).

Milestones that are critical to the authors project include are those highlighted as the challenges in 6.2.2 decanting, sorting and feeding ties. Only once these milestones are achieved can the strategy to implement the solution at site can be planned. As Tubex is a seasonal business it would make sense to install the innovation in the quite period when lines can be stopped without impacting orders. This takes the pressure off the integrator and project manager with time restraints to install and get rid of any snagging issues almost removed albeit sticking to schedule as much as possible is still preferred.

8- Finance

8.1- Financial analysis

Prior to any capital allocation towards a project, company policy requires three quotations for investments of more than £50,000 so three automation integrators will need to be approached to provide solutions for the line automation. The estimated budget cost would have to be under £3Million to fit with 3 year payback (calculation in appendices 10.4).

The automated solution must be capable of a cycle time of 5 seconds per 1.2m tube, equalling the maximum extruding speed. The automated solution therefore increases productivity by a factor of 2.2 and increases extruding machine utilisation.

The successful integrator will be chosen based on running operation, its reputation and the in-house skills it possesses to ensure that any problems would be dealt with by the same core team without the need to engage with sub-contactors (Worster, et al., 2013). Key financial analysis such as payback period (PP), Net present value (NPV) and internal rate of return (IRR) will be key indicators in the project financials and further details can be found in the appendices.

8.2-Project financial analysis

The project Analysis indicates that the payback just exceeds the 3 years that is required for local Capex approval but is still a very viable project as it falls under the 5 year threshold. Within Berry projects with payback of under 2 years has local sign off, 3-5 would require a deeper presentation on the project and over 5 would need a direct report to corporate finance and the Capital committee.

The project sees a positive NPV with a WACC of 10%

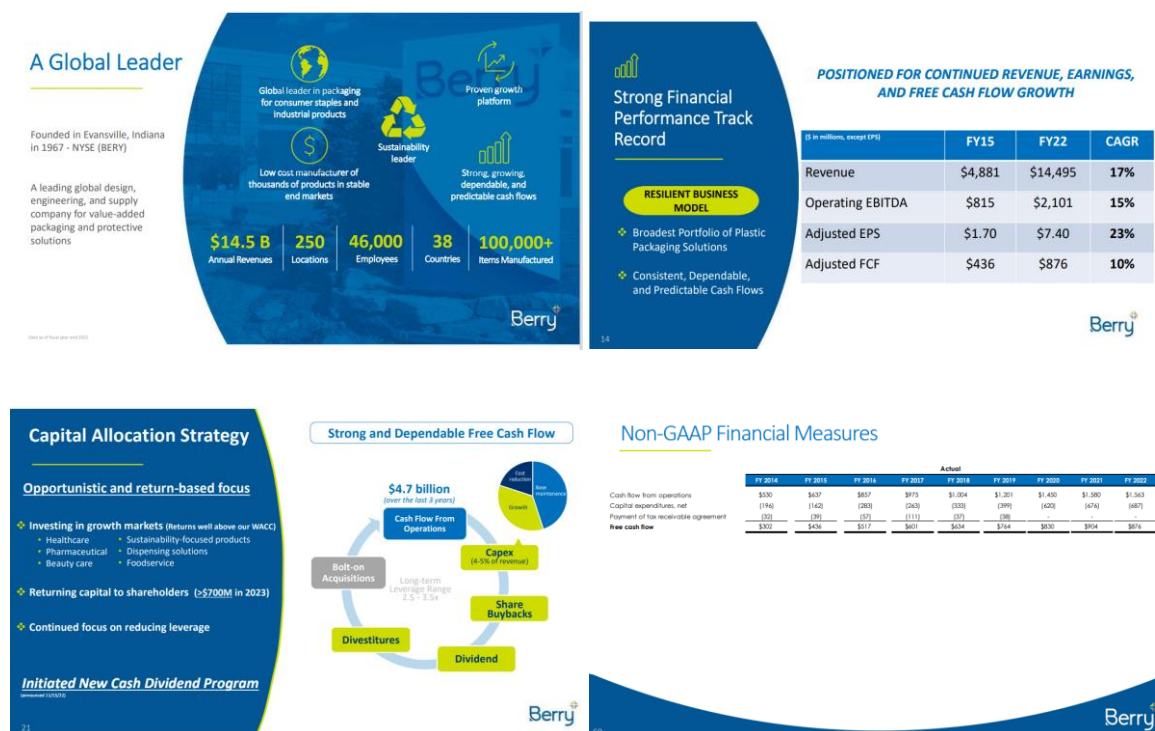
The metric Berry would be more interested in for Capital expenditure alongside EBITDA is IRR which for this project is a positive 23.53% and a positive incremental EBITDA of £182k/5years.

Project Analysis

	investment	Yr1	Yr2	Yr3	Yr4	Yr5
Present value	-482,150	168,462	171,831	175,268	178,773	182,349
Discount Rate (WACC)	10%					
Denominator	1.000	0.909	0.826	0.751	0.683	0.621
Future value	-482,150	153,132	141,933	131,626	122,102	113,239
NPV	179,881					
Pay back	3.17					
NPV using excel	180,017					
IRR	23.53%					
ARR	26.67%					
PI	1.37	660,546				
BCR	0.37					

Total Cashflow	876,683
Depreciation	701,346
Net income	175,337
project length	10
Average	17,534
ARR	26.67%

Funding options- Berry Global tend to capitalise most projects themselves but I have also once been involved in a project so Berry that did have partial Government funding. That particular project was during COVID and had a direct impact towards the pandemic so securing funding was easier and more widely available. (Global, 2023). Further workings can be found in Appendices 10.4.



New Temporary Tax Reliefs on Qualifying Capital Asset Investments were introduced from 1 April 2021 relating to temporarily increased tax relief on expenditure for plant and machinery. This measure is designed to stimulate business investment. Capital allowances allow businesses to write off the costs of tangible capital assets, such as plant or machinery, against their taxable income. They take the place of commercial depreciation, which is not an allowable tax deduction. A project such as this may require intercompany transactions due to timings of the investment. As Tubex is a seasonal business project work has to be implemented when the lines are quiet but this is also the time when the company makes the least amount of profit. Given this there is a chance that the Capital will be moved inter- company from a Berry Division that is making more profit at that time.

9-Current conclusion, commendation and closing

This report has assessed the implications of adopting automation and robotics in an industry and area that is culturally and technically challenged. There is also the uncertainty of labour availability in a sector paying not a lot more than minimum wage. Manufacturers in the area such as GAP plastics and Prysmian group are also encouraging innovation which has been highlighted in the appendices of their financial statements available on company's house. Arguments could be made that they're innovation outside of PD is aligned with the authors due to the lack of steady labour within the valley. Manufacturing and process changes may be required with the introduction of automation as with increased available packing speed the bottle necks will most certainly move to another part of the process. Whilst automation sound like an easy solution to help business thrive, the challenges highlighted in this report stem from the authors product being very bespoke and no off the shelf solutions available. Every solution will effectively be a new invention albeit based on similar solutions in the form of other equipment. Components are available but the challenge is turning the components into a functioning machine. There are many critical challenges to cover that's been highlighted and it is essential that research and due diligence is completed in collaboration between Tubex and the successful integrator to ensure the right components and solutions are designed. Fundamental indicators to the innovation are using external expertise from suppliers, OEM's and potentially universities along with prototyping and proof of concepts on design. Repeatability is key with the ramp up from workshop tests to cycle after cycle accuracy, a point that has been highlighted as requiring an increased focus when the time comes to install at the gemba.

Whilst carrying out research in to various topics with in this report the author has to highlight how important training and education is with not just innovation but within manufacturing as a whole and at all levels. One could argue that the finding of this dissertation has highlighted the gap between skillsets on site and within the valley. Engineers, technicians and setters could easily become exposed with the introduction of Robotics and advanced automation. Professional training, Training matrixes and SOP (safe operation procedure) quality all suggest the company may not yet be ready for this innovation at least not until the above points are actioned.

To support the skillset gap, researching and understanding best practices are important, however a company must be able to apply the knowledge to their specific business and finding UK based experts on extrusion seems to be scarce. Automation integrators through are more readily available and further research into integrators that suit this kind of project needs to be followed up on. Integrators that can provide case studies of similar kinds of projects with good project management and have modern facilities would be the type of company to support this project. The author would

be required to create a robust presentation highlighting the benefits to support Capex applications and also investigate funding schemes that may be available from government grants etc.

The final stages of the project success will be implementation as it will have to be planned in a way that it's not too disruptive to manufacturing continuing.

9.2-Implementation

Implementation of the project would have to consider the amount of time the manufacturing lines will be unavailable and this will be defined by the final project design. If the design is modular the install may have limited disruption to the current manufacturing lines but if the design is more of a fixed design then advanced planning is essential. Timings on installation will need to be critically set out so that the innovation is completed in time for planned factory shutdowns in the quieter manufacturing times.

9.2-Next steps

The financial analysis indicates that the innovation has a strong business case and if integrators can present they're proposals and proof of concepts using digital twins or simulations then there is a chance that this innovation will gain corporate approval.

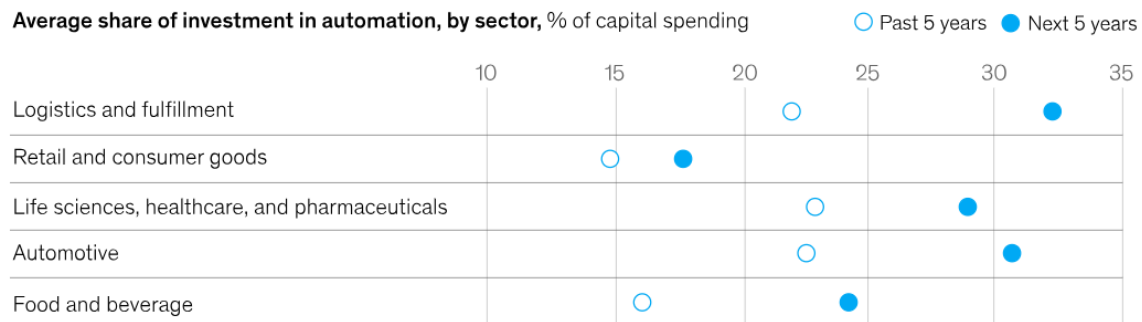
9.3-Limitations

Difficulties will arise when attempting to present the innovation to the corporate board. It is likely that the board based in the USA would have never seen the manufacturing site in person so will be reliant on presentations and data to drive decisions on approval and finance release.

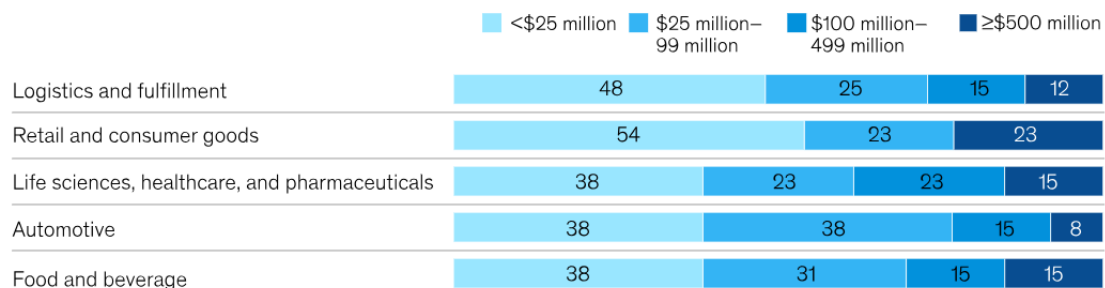
10-Appendices

10.1-Market studies

Automation will account for 25 percent of industrial companies' capital spending over the next five years.



Anticipated amount of investment in automation over next 5 years, by sector, % of respondents

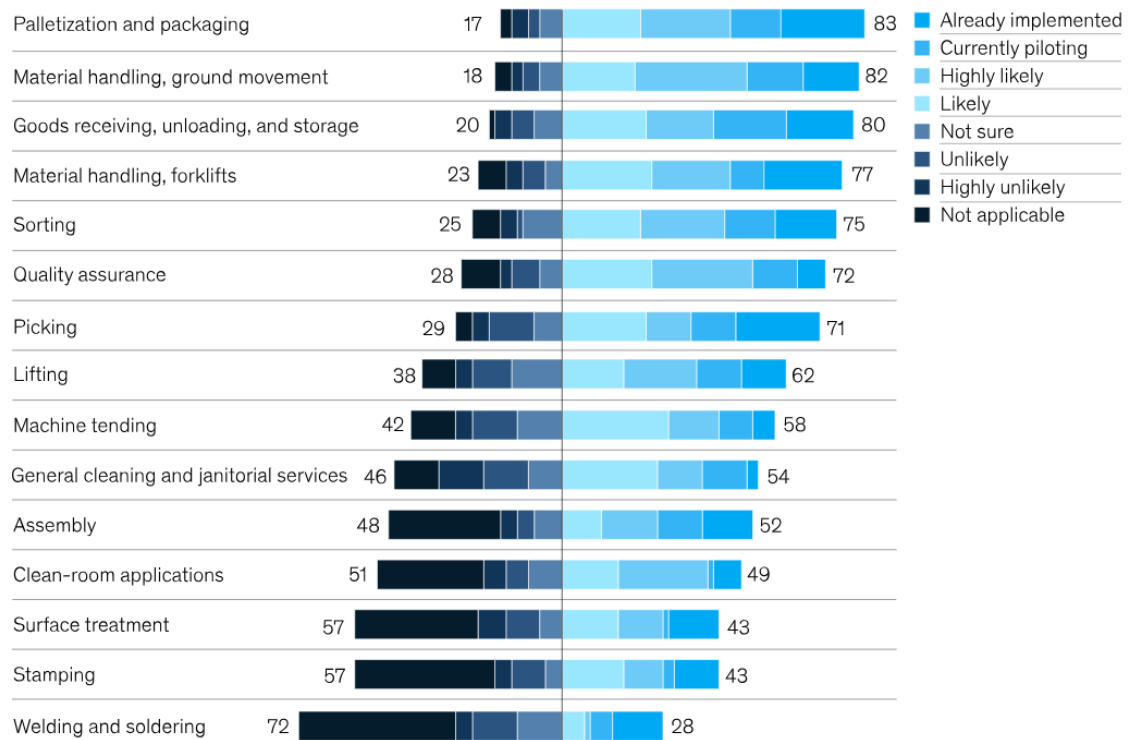


Source: McKinsey Global Industrial Robotics Survey, 65 senior leaders and executives in automotive; food and beverage; life sciences, healthcare, and pharmaceuticals; logistics and fulfillment; and retail and consumer goods sectors, August 2022

McKinsey & Company

The key use cases for automation in industrial companies include material handling, palletization, and sorting.

Likelihood of automation adoption, by use case, % of respondents



(Mckinsey, 2023)

10.2-Berry participant forms

The leadership team and engineering team at Tubex are the drivers of most innovative projects but feedback from the Gemba is encouraged. Awareness of Industry 4.0 and automation is of a nominal level with in the above group but essential feedback from the maintenance team is required. This qualitative data collected from the questions asked will help understand the reality of other employee groups at Tubex.

Please answer question honestly and if unsure please tick box 3 in each question criteria.

Maintenance		Essential	Very important	Not essential	No importance	Unaware
Question						
1 How do you perceive industry 4.0 in manufacturing			x			
2 How important is automation in Tubex	x					
3 How important is business evolution	x					
4 How critical is digitalisation		x				
5 What are the feelings on training	x					
6 Are you aware of IOT	Yes	No	Some knowledge			
7 Do you think automation can help Tubex	x					
8 Do you think your current skillset can support innovation				x		
9 Do you see Tubex as a smart manufacturer				x		
10 Do you get given a change to initiate change	x					
11 Do you feel the process can be further automated	Yes	No	Maybe			
12 Do you see automation as advantageous	x					
13 Do you feel automation can help your working day	x					
14 Do you see any ethical issues with automation				x		
15 Do you feel introducing automation can help your development				x		





The leadership team and engineering team at Tubex are the drivers of most innovative projects but feedback from the Gemba is encouraged. Awareness of Industry 4.0 and automation is of a nominal level with in the above group but essential feedback from the cell leaders is required. This qualitative data collected from the questions asked will help understand the reality of other employee groups at Tubex.

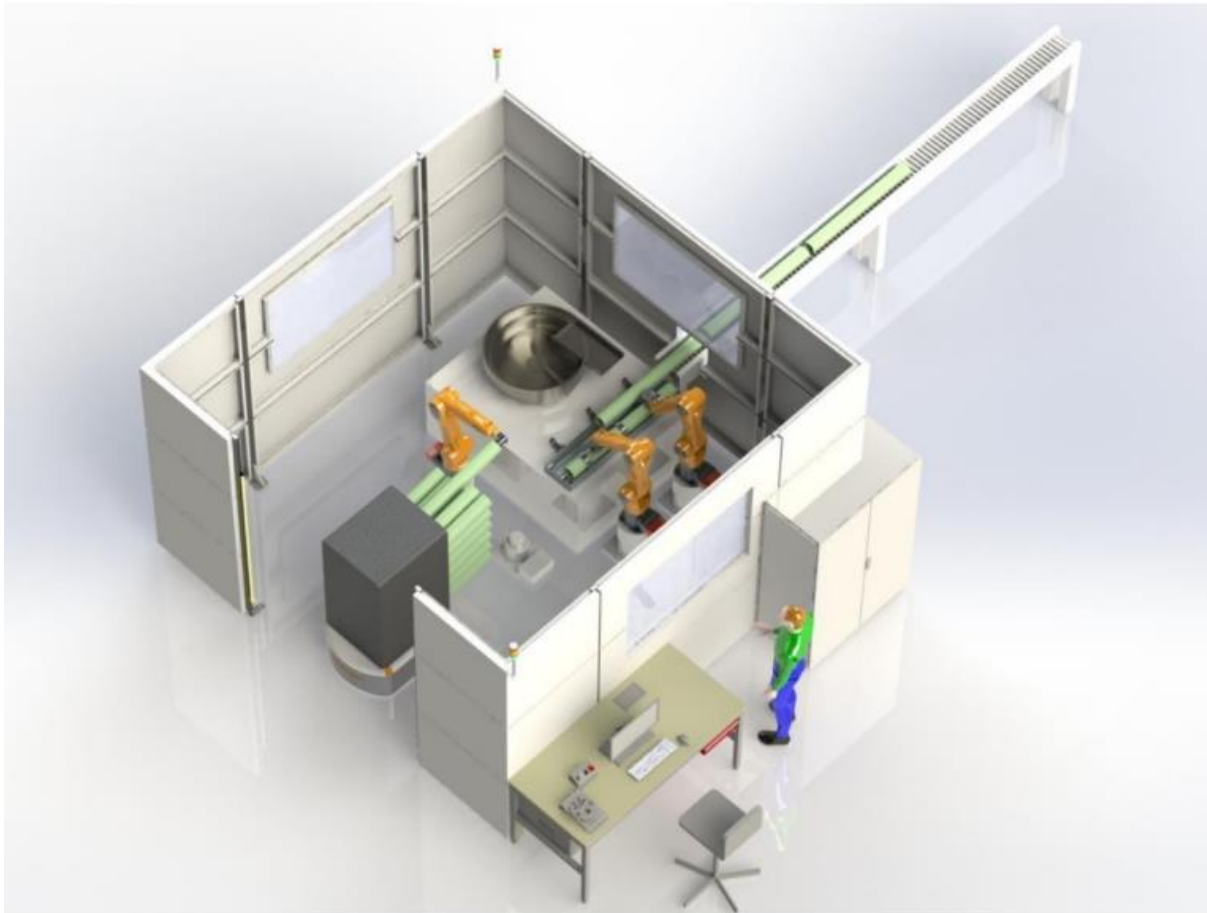
Please answer question honestly and if unsure please tick box 3 in each question criteria.

Line leader		Essential	Very important	Not essential	No importance	Unaware
Question						
1 How do you perceive industry 4.0 in manufacturing				x		
2 How important is automation in Tubex			x			
3 How important is business evolution			x			
4 How critical is digitalisation				x		
5 What are the feelings on training	x					
6 Are you aware of IOT	Yes	No	Some knowledge			
7 Do you think automation can help Tubex	x			x		
8 Do you think your current skillset can support innovation			x			
9 Do you see Tubex as a smart manufacturer				x		
10 Do you get given a change to initiate change	x					
11 Do you feel the process can be further automated	Yes	No	Maybe			
12 Do you see automation as advantageous	x					
13 Do you feel automation can help your working day				x		
14 Do you see any ethical issues with automation				x		
15 Do you feel introducing automation can help your development	x					

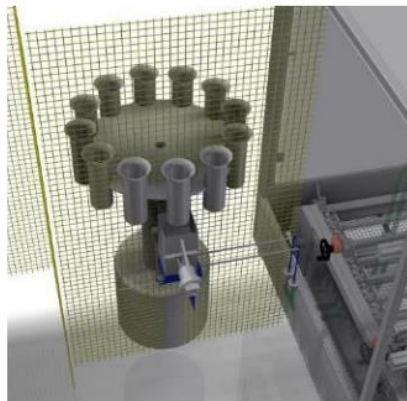
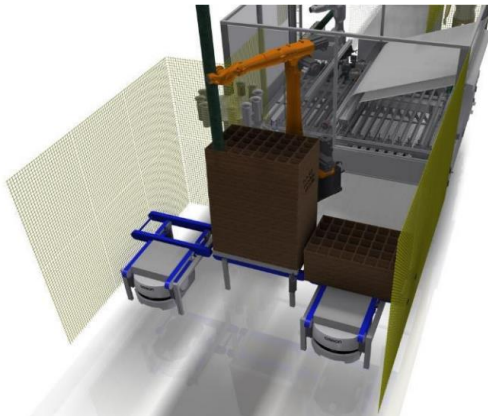
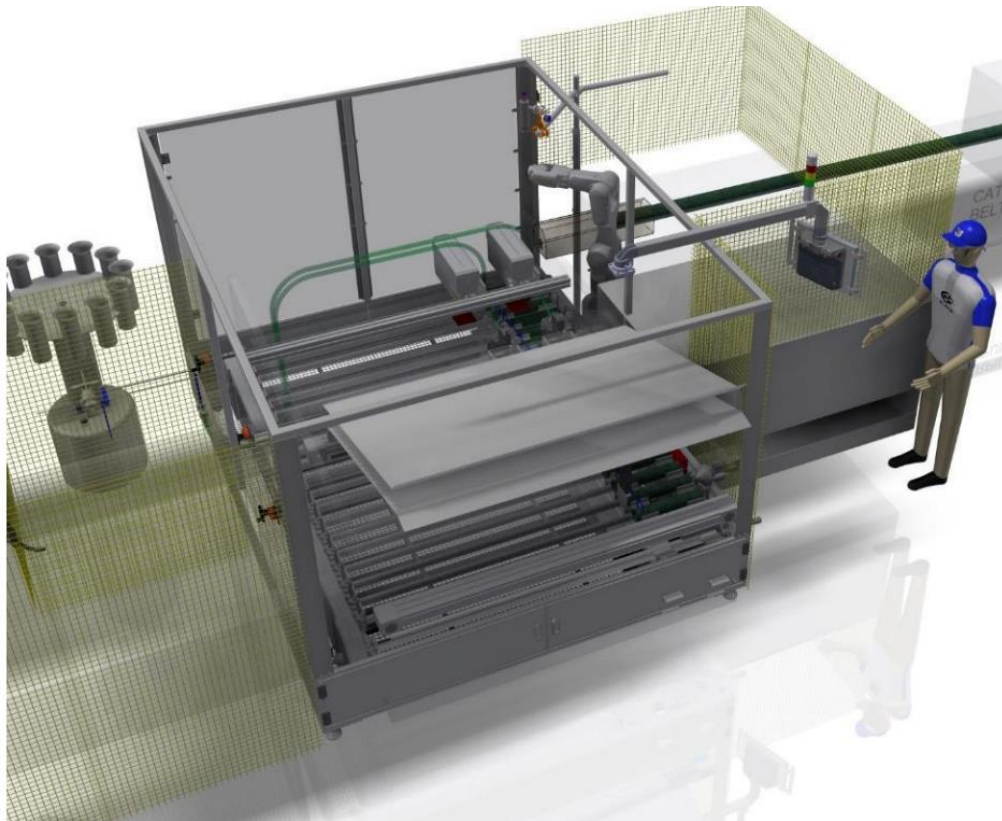




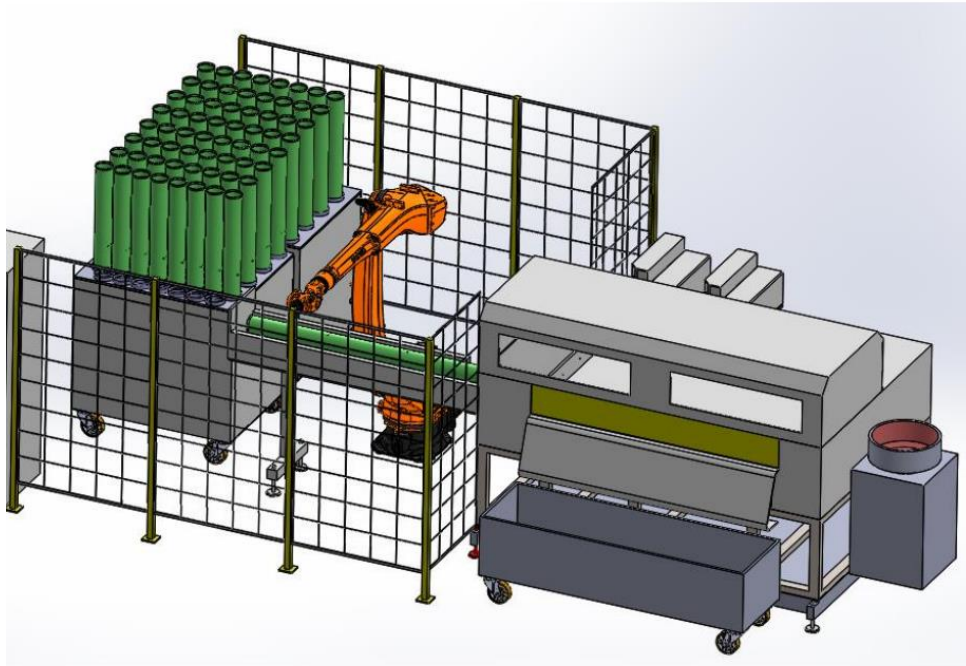
10.3-Integrator 1 Concept



10.3-Integrator 2 Concept



10.3-Integrator 3 Concept



10.4-Financial analysis



Introduction

- In 1978 the first tree shelters were conceived and trailed by Graham Tuley of the UK Forestry Commission.
- Since then, Tubex have been researching and refining the range to offer increased benefits and establish safeguards as identified through many trials.
- The conversion part of the process involves inserting a tie into the tree shelter and its very labour intensive.
- Week on week labour fulfilment percentages are not getting better than 89% so how do we find the missing 11%? Is Robotics the answer?
- Within a manufacturing line that is very labour intensive due to the dextrous nature of the task, questions have been asked for many years if Robots can be used to support staff.
- Inefficiency's are currently with attracting temporary labour that has to remain temporary due to the seasonality of the business.



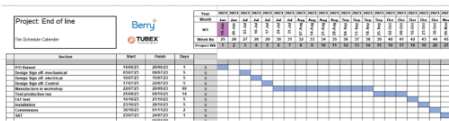
What does the project bring to the business

1st phase	Capex	Benefit hrs	Benefit	Payback Est
	482150	8527	124468	3- 5 years

- Fully automated end of line
- Product output improvement
- 8527 Labour hours saved
- Labour variance stands between 6 and 45 for temporary staff
- Difficulty to hire, churn rate = 1/3
- Inventory build-up needed
- Impact on lead time & sales during high season
- Cost avoidance on current machine guarding upgrade (~300k\$ per line)
- Improved Safety conditions
- Reduced administrative complexity during busy business season



Time line of implementation



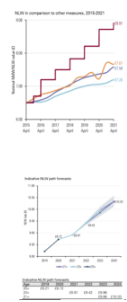
- 21 weeks between order & line start
- 18 weeks between order & Factory acceptance test (FAT)
- FAT conditions very close to productions conditions
- Timing to be refined depending on how we want to approach installation
- Inventory build-up needed in case of installation during high season (There will be a cost required to build inventory).



Cost of the project

Steps	Task	GBP (£)
1 Phase	End of line Automation	477150
1 Phase	Additional (ancillary)	5000
1 Phase	Total	482150

- Many organisations outside of the aviation or automation industry have been slow with the uptake of Robotics, with the message being the availability of cheap flexible labour out weighs the investment into technology (Payne, 2019)
- This may have worked in the past but is no longer relevant due increasing labour costs.
- There will be risks relative to improving technology and recent studies refer to a shortages of skills in relation to a small group of specialists, such as engineers at the interface with IT and programming skills.



Basic payback

Payback Period	Investment	Y1	Y2	Y3	Y4	Y5
Present value	482,150	104,402	171,851	175,268	174,775	182,140
Pay back Yrs	2.81	0	0.81			



Life span

- For a project of this size the payback will have to be under 5 years but the lifespan of the project will be 10 years.
- Berry will depreciate the assets for 10 years as part of EBITDA.
- Robots can be used in different applications at end of life due to their build.



Ethics and disruption

- A key statement in this project charter is that ethically we don't want Robots to replace employees. These days Robots are also leaving industrial setting and entering every day life (economist 02/22)
- There is a place for both in our company but the main driver of the research is to ensure that we can fill the 11% gap without the reliance of temporary labour.
- If we could fill our vacancies 100% of the time and maximise line through put then a proposal such as this wouldn't exist.
- There will obviously be some vacancies lost to the robots but installing Robots will also create other jobs for more highly skilled employees. Worldwide installations of industrial robots from 2004 to 2020, with a forecast through 2024 is shown in the graph (Statista, Nov 2022)



Business rational

- Positive NPV
- Payback 3.17
- IRR 23.5%

	Investment	Y1	Y2	Y3	Y4	Y5
Present value	482,150	104,402	171,851	175,268	174,775	182,140
Discount Rate (WACC)	3.0%					
Discount factor		0.971	0.942	0.913	0.885	0.857
Present value	482,150	101,110	161,910	159,426	153,100	155,479
NPV		179,441	149,538	141,495	140,481	137,680
Pay back	3.17					
NPV using excel		180,012				

	Investment	Y1	Y2	Y3	Y4	Y5
Present value	482,150	104,402	171,851	175,268	174,775	182,140
Discount Rate (WACC)	3.0%					
Discount factor		0.971	0.942	0.913	0.885	0.857
Present value	482,150	101,110	161,910	159,426	153,100	155,479
NPV		179,441	149,538	141,495	140,481	137,680
Pay back	3.17					
NPV using excel		180,012				



Project funding options

- Internal Berry Global Capex
- Berry has a strong financial performance
- Capex can be shared within group and not just locally
- Tax Reliefs on Qualifying Capital Asset Investments available and currently being applied



Conclusion and recommendation

	Investment
Present value	-482,150
Discount Rate (WACC)	10%
Denominator	1.000
Future value	-482,150
NPV	179,881
Pay back	3.17
NPV using excel	180,017
IRR	23.53%
ARR	26.67%
PI	1.37
BCR	0.37

Total Cashflow	876,683
Depreciation	701,346
Net income	175,337

- The project sees a positive NPV with a WACC of 10%
- The metric Berry would be more interested in for Capital expenditure alongside EBITDA is IRR
- IRR for this project is a positive 23.53%. and a positive incremental EBITDA of £182k/5years.

Appendices

ARR - accounting rate of return

	Investment	Yr1	Yr2	Yr3	Yr4	Yr5
Present value	-482,150	168,462	171,831	175,268	178,773	182,349
Discount Rate (WACC)	10%					
Denominator	1.000	0.909	0.826	0.751	0.683	0.621
Future value	-482,150	153,132	141,933	131,626	122,102	113,239
NPV	179,881					
Pay back	3.17					
NPV using excel	180,017					
IRR	23.53%					

Cash in	E	Residual Value
Yr1	168,462	175,268
Yr2	171,831	178,773
Yr3	175,268	182,349
Yr4	178,773	
Yr5	182,349	
Total cash flow	876,683	
Depreciation	701,346	
Average annual profit	87,668	

Total profit	Years	Average
87,668	10	8,766.8

Investment	Residual	Average
-482,150	175,337	338,713

ARR	87,668	100%	=	27%
	328,743			

$$\text{Annual Rate of Return} = \frac{\text{Average Annual Profit}}{\text{Initial Investment} + \text{Future Residual Value} / 2}$$

Project Analysis

	Investment	Yr1	Yr2	Yr3	Yr4	Yr5
Present value	-482,150	168,462	171,831	175,268	178,773	182,349
Discount Rate (WACC)	10%					
Denominator	1.000	0.909	0.826	0.751	0.683	0.621
Future value	-482,150	153,132	141,933	131,626	122,102	113,239
NPV	179,881					
Pay back	3.17					
NPV using excel	180,017					
IRR	23.53%					
ARR	26.67%					
PI	1.37	660,546				
BCR	0.37					

Total Cashflow	876,683
Depreciation	701,346
Net income	175,337
project length	10
Average	17,534
ARR	26.67%

Appendices

Calculating NPV

	Investment	Yr1	Yr2	Yr3	Yr4	Yr5
Present value	-482,150	168,462	171,831	175,268	178,773	182,349
Discount Rate (WACC)	10%					
Denominator	1.000	0.909	0.826	0.751	0.683	0.621
Future value	-482,150	153,132	141,933	131,626	122,102	113,239
NPV	179,881	-325,018	-187,085	-55,459	66,643	179,881
Pay back	3.17					
NPV using excel	180,017					

Profitability Index

Project A

	Investment	Yr1	Yr2	Yr3	Yr4	Yr5
Present value	-482,150	168,462	171,831	175,268	178,773	182,349
Discount Rate (WACC)	10%					
Denominator	1.000	0.909	0.826	0.751	0.683	0.621
Future value	-482,150	153,132	141,933	131,626	122,102	113,239
NPV	179,881					
Pay back	3.17					
NPV using excel	180,017					
IRR	23.53%					

$$PI = \frac{PV \text{ of future cash}}{Investment} = \frac{662,031}{482,150} = 1.37$$

Payback Period

	Investment	Yr1	Yr2	Yr3	Yr4	Yr5
Present value	-482,150	168,462	171,831	175,268	178,773	182,349
Discount Rate (WACC)	10%					
Denominator	1.000	0.909	0.826	0.751	0.683	0.621
Future value	-482,150	153,132	141,933	131,626	122,102	113,239
Pay back Yrs	3.17					

BCR

Project A

	Investment	Yr1	Yr2	Yr3	Yr4	Yr5
Present value	-482,150	168,462	171,831	175,268	178,773	182,349
Discount Rate (WACC)	10%					
Denominator	1.000	0.909	0.826	0.751	0.683	0.621
Future value	-482,150	153,132	141,933	131,626	122,102	113,239
NPV	179,881					
Pay back	3.17					
NPV using excel	180,017					
IRR	23.53%					

$$BCR = \frac{NPV}{Investment} = \frac{180,017}{482,150} = 0.37$$

10.5- Dissertation readings

University 2022 > 3.Assignment 3-research proposal

Search 3.A...

Alan mumbly

Dissertation Final

1.6...Regulating artificial intelligence and robotics ethics by design in a digital society

2.1 organisation culture

2.4. People vs machine

2.4....1-s2.0-S0927537118300228-main

2.5.S2351978920307472

2.5a.S2351978920307472

3.1 The New Plastics Economy_ Rethinking the future of plastics

3.1-3.2-3.3. MyerKutz_2011_151Introduction_AppliedPlasticsEngine

3.1-3.2-3.3.A MyerKutz_2011_159SolidificationAndC_AppliedPlasticsEngine

3.1-3.2-3.3.B MyerKutz_2011_92NaturallyOccurringB_AppliedPlasticsEngine

3.2...polymers-12-01306

3.2-3.3.Advanced_Automation_and_Robotics_for_High_Volume_Labour-Intensive_Manufacturing

4.1 Robots_in_Industry_The_Past_Present_and_Future_of_a_Growing_Collaboration_With_Humans

4.2 delivering-economic-transformation-for-a-better-future-of-work

4.2...apo-nid254996

4.2...MPhil+Thesis++Evaluating+the+impact+of+automation+on+labour+markets+in+England+and+Wales

4.3.1-s2.0-S2352146521004543-main

4.4.A_Novel_Soft_Sensor_Approach_of_Polymer_Process_for_Resin_Monitoring_Based_on_Melt_Pressure_Spectrum

4.6.A_Perspective_on_Education_to_Support_Industry_4.0_A_Qualitative_Case_Study_in_UK

6.0 Robotics and autonomous systems

6.1.An_application_of_robotic_cable_harness_br

6.1.Designing_Robots_for_Reachability_and_De

6.2.The_design_development_of_automated_pi

6.2.5 1-s2.0-S2212827118300817-main

6.3.1-s2.0-S0278612521001151-main

7.retrieve

7.1 information-11-00116-v2

7.1.S309-Article Text-17064-4-10-2010721

7.1.hamrol_gawlik_sladek_mechanical_3_2019 (

7.2.1-s2.0-S2666351121000310-main

7.2.Online_Fault_Detection_a_Smart_Approach_

7.3.1-s2.0-S266635112100053X-main

7.3.applsci-09-03815-v2 (1)

7.3.s10845-021-01748-5

7.4.S2212827120303978

7.6.designs-04-00011-v2 Copy

2020_Book_TechnicalEconomicAndSocietalEf

Dissertation 05-02-24 Darren B

Dissertation draft

Dissertation

	Reference 1- Web	Reference 2-Journal	Reference 3
1- Introduction			
1.1 Introduction Brief	https://www.forbes.com/sites/forbesfinancecouncil/2020/07/18/8-strategies-to-help-a-seasonal-business-avoid-a-sales-slump/		https://www.accountingtools.com/articles/manufacturing-costs
1.2 Aim (benefits against challenges)			
1.3 Objective (what I will analyse)			
1.4 Justification (impact of lack of labour)	https://the.cochrane.org/ucsg/2016/02/03/additional-reviews-vs-systematic-reviews/		
1.5 Methods (research methods)			
1.6 Ethics (ethical impact of not using temp lab)	Process Automation Ethics: Navigating the Moral Dilemmas (linkedin.com)	Regulating artificial intelligence and robotics: ethics by design in a digital society (united.ac.uk)	Automation and Ethics SpringerLink
2-Culture			
2.1 Organisational culture- from private to corporate owned (corporate impact)	Two years after being sold to Coke, has this company kept its innocence? (theguardian.com)	The Organizational Culture in Public and Private Institutions (sciencedirectassets.com)	https://www.researchgate.net/publication/308250_The_Damned_Christian_Merger_-_a_cultural_mismatch
2.2 Company history- (How the company started and go to where it is now. About me and my dissertation. The dissertation is written as an independent academic not for)	Tubex.co.uk		
2.3 Area culture- Valley culture and unemployment		ASHTLEY_A329_RVDR.pdf (open)	Rhonda Cymon Taf's employment, unemployment and economic inactivity - Plastic pollution has been in use since the early 19th century, when a few different inventors contributed to its rise (linkedin.com)
2.4 Industry culture-	Thermoplastics (bpf.co.uk)		
2.5 Leadership	Characteristics and Skills of Leadership (main.pdf (sciencedirectassets.com))		
3-Technology			
3.1 Technology in plastic manufacturing- where is the industry at plastic based culture - Details behind the innovation- How the company lacked innovation for a long time. Demonstrate your 3.1 Technology in extrusion- has it moved on?	What's Changed — and What Hasn't — in Extrusion Technology (plasticalday.com)	The New Plastics Economy: Rethinking the future of plastics.pdf (thudlight.com)	
3.2 Innovation in extrusion- How much over the last 20 years?	MyerKutz_2011_92NaturallyOccurringB_AppliedPlasticsEngine.pdf	MyerKutz_2011_159SolidificationAndC_AppliedPlasticsEngine.pdf	MyerKutz_2011_151Introduction_AppliedPlasticsEngine.pdf
4- Automation and Robotics			
4.1 History- industry 4.0 leading up to automation etc	Robots_in_Industry_The_Past_Present_and_Future_of_a_Growing_Collaboration_With_Humans.pdf		

	Reference 1- Web	Reference 2- Journal	Reference 3
4.2 Automation in Wales- How do we compare to the UK, Europe etc.	4.2...apo-nid254996.pdf	Microsoft Word - Evaluating the impact of automation on labour markets in England and Wales - Anil Frasher (ox.ac.uk) Saved	4.2...MPhil+Thesis++Evaluating+the+impact+of+automation+on+labour+markets+in+england+and+wales.pdf
4.3 Automation in Manufacturing- different sector comparisons	The UK Robotics Industry: August 2023 Update (linkedin.com)	main.pdf (sciencedirectassets.com)	
4.4 Automation in the sector- Specialists or not?		IEEE_Xplore_Full-Text_PDF	
4.5 A look into independent integrators- Who are the specialists?			
4.6 Innovation support- Who can support and how to get support?	Robotics Career - Robotic Skills That Can Help You in a Career in Robotics	IEEE_Xplore_Full-Text_PDF	GF Aerospace Wales opens new training academy in Nantgare (wales247.co.uk)
5- Automation Robotics			
5.1 Automation and Robotics OEM's in Berry	Plastics Innovation in Packaging & Invention for Brands Berry Global	Berry Completes "Center of Excellence" with A.Celli Norwovens (a-cellul)	How Berry Superfos controls their layers Reifenhauser
5.2 Automation and robotics a case study in South Wales			
5.3 Automation and robotics case study in Berry		How Berry Superfos controls their layers Reifenhauser	
5.4 Automating the missing 11%			
6- Implementation			
6.1 The manufacturing facility- where we are at now	Using D365 for Project Management - Learn Sigma Corporation	IEEE_Xplore_Full-Text_PDF	
6.2 Research			
6.2.1 Integrator selection	New Factors for Choosing a Right System Integrator (linkedin.com)	IEEE_Xplore_Full-Text_PDF	
6.2.2 Challenges- Tie Sorting, Tie insertion, nesting of p	121 "10 Advantages of PLC Systems in Industrial Automation" LinkedIn	Research on a design method of pneumatic logic control system - Wangling Liu, Qun Sun, 2021 (sagepub.com)	Capital Allowances for Plant and Machinery Toolkit 2022 uk (live.com)
6.2.3 Technical specification and performance	Machine Builders UK What is a UBS? Who is it important? - 5F Automation & Robotics (link-automation.co.uk)	IEEE_Xplore_Full-Text_PDF	
6.2.4 Ethics	5 Common Barriers to Automation & How to Solve Them (worksaf.com)	What is Assembly Line Automation Link Automation	Shifting a Balance: Ethical Considerations in Workplace Automation
6.2.5 Cycle by cycle performance- The process, repeatability, rejections, QC inspections, FMEA	Optimize Assembly Line Layout: Tips and Tricks (linkedin.com)	6-2-5-1-2-1-2-5-2-2-1-2-8-2-7-1-8-3-0-0-8-1-7-main.pdf	
6.3 Proposed line assembly plan- where we want to be		Digital twins-based smart manufacturing system design in Industry 4.0: A review - ScienceDirect	
7- Concepts	Industry 4.0: Clustering of concepts and relationships - ESOP 7-2014		

10.6-Bibliography

Akyar, I., 2012. Standard operating procedures. In: INtECH, ed. *Latest research into quality control*. Rijeka: s.n., p. 504.

Anna, R. A. S., 2021. *Rapid Prototyping in Industry 4.0*. [Online]
Available at: <https://www.linkedin.com/pulse/rapid-prototyping-industry-40-renato-azevedo-sant-anna>
[Accessed 17 02 2023].

ARCOS, n.d. [Online]
Available at: <https://www.arcossrl.com/en/industrial-robotic-automation-what-it-is-and-what-are-the-benefits-for-industries/#:~:text=Industrial%20robotics%20is%20a%20secondary%20branch%20in%20industrial,of%20tasks%20alongside%20or%20in%20place%20of%20humans>

Automate, 2019. *What is an End Effector and How Do You Use One?*. [Online]
Available at: <https://www.automate.org/news/what-is-an-end-effector-and-how-do-you-use-one>
[Accessed 05 02 2024].

Automation, C. d., 2021. *Fanuc*. [Online]
Available at: <https://www.controlsdrivesautomation.com/FANUC-supply-Ford-Cologne-robots>
[Accessed 11 02 2024].

Automation, J., n.d. *WHAT IS ASSEMBLY LINE AUTOMATION?*. [Online]
Available at: <https://www.jrautomation.com/resources/what-is-assembly-line-automation#:~:text=A%20fully%20automated%20production%20line,little%20to%20no%20human%20intervention.>
[Accessed 07 02 2024].

automation, W., 2023. *"10 Advantages of PLC Systems in Industrial Automation"*. [Online]
Available at: <https://www.linkedin.com/pulse/10-advantages-plc-systems-industrial-automation-solutions/>
[Accessed 12 02 2024].

Bartos, M. et al., 2021. An overview of Robot application in automotive industry. *14th International scientific conference on sustainable, modern and safe transport*, p. 8.

Berry, 2023. *Berry innovation*. [Online]
Available at: <https://www.berryglobal.com/en/about-us/innovation>
[Accessed 11 02 2024].

Blidaru, A., Smith, L. S. & Kulic, D., 2018. *Assessing user specifications for robot task planning*. Nanjing, IEEE, p. 8.

Bodkin, P., 2015. *The Journal*. [Online]
Available at: <https://www.thejournal.ie/innocent-drinks-coca-cola-2073030-May2015/>
[Accessed 06 01 2024].

bravo, J., 1986. *An application of robotic cable harness bundling*. San francisco, IEE.

Brown, P., 2019. *Delivering Economic Transformation for a Better Future of Work*, cardiff: Welsh Government.

- Butt, J., 2020. *A Strategic Roadmap for the Manufacturing Industry*, Chelmsford: MDPI.
- career, R., 2022. *Do You Already Have Robotics Skills*. [Online]
Available at: <https://www.roboticscareer.org/news-and-events/news/25216>
[Accessed 03 02 2023].
- Cohen, Y. & Singer, G., 2021. A smart process controller framework for Industry 4.0 settings. *Journal of Intelligent Manufacturing*, p. 21.
- Demeyin, W., 2016. *Traditional reviews vs. systematic reviews*. [Online]
Available at: <https://s4be.cochrane.org/blog/2016/02/03/traditional-reviews-vs-systematic-reviews/>
[Accessed 26 11 2023].
- Development, C. I. o. P. a., 2019. *Addressing employer underinvestmmet in training*, London: s.n.
- Dweck, D., 2019. *5 Smart Strategies to Improve Project Management in Manufacturing*. [Online]
Available at: https://www.linkedin.com/pulse/5-smart-strategies-improve-project-management-douglas-dweck?trk=pulse-article_more-articles_related-content-card
[Accessed 19 02 2024].
- Eisner, C., 2022. *What Are the Advantages of Using Standard Operating Procedures?*. [Online]
Available at: <https://www.getmaintainx.com/blog/what-are-the-advantages-of-using-standard-operating-procedures/>
- Engtal, 2021. *What does Industry 4.0 mean for mechanical engineering?*. [Online]
Available at: <https://www.linkedin.com/pulse/what-does-industry-40-mean-mechanical-engineering-engtal>
[Accessed 17 02 2024].
- Eurodrive, S., 2024. *AC motors, asynchronous motors*. [Online]
Available at: https://www.seweurodrive.com/products/motors/ac_motors/ac_motors.html
[Accessed 17 02 2024].
- Fawcett, J. & Russell, G., 2019. *A 21st century skills system for wales*, Edinburgh: Institute for Public Policy Research.
- Forbes, 2023. *14 Strategies To Help A Seasonal Business Avoid A ‘Sales Slump’*. [Online]
Available at: <https://www.forbes.com/sites/forbesfinancecouncil/2023/01/18/14-strategies-to-help-a-seasonal-business-avoid-a-sales-slump/>
[Accessed 26 11 2023].
- Gasparetto, A. a. S. L., 2019. *A Brief History of Industrial Robotics in the 20th Century*. [Online]
Available at: <https://www.scirp.org/journal/paperinformation.aspx?paperid=90517>
- Gill, R., 2003. Change management — or change leadership. p. 13.
- Global, B., 2023. *Investor presentation*. [Online]
Available at: <https://ir.berryglobal.com/static-files/a5ad688a-f91c-4e9b-a697-998ca912904a>
- Grau, A., Indri, M., Lo Bella, L. & Thilo, S., 2020. The Past, Present, and Future of a Growing Collaboration With Humans. *Robots in Industry*, Issue 1, p. 11.
- Gregory, R., 2023. *GE Aerospace Wales opens new training academy in Nantgarw*. [Online]
Available at: <https://www.wales247.co.uk/ge-aerospace-wales-opens-new-training-academy-in->

nantgarw

[Accessed 11 01 2024].

Griff, A., 2021. *What's Changed — and What Hasn't — in Extrusion Technology*. [Online]

Available at: <https://www.plasticstoday.com/extrusion-pipe-profile/what-s-changed-and-what-hasn-t-in-extrusion-technology>

[Accessed 02 02 2024].

Guzman, V. E. et al., 2020. Characteristics and Skills of Leadership in the Context of Industry 4.0.

Procedia Manufacturing, Issue 20201, p. 8.

Hamrol, A., Gawlik, J. & Stadek, J., 2019. MECHANICAL ENGINEERING IN INDUSTRY 4.0. *Management and Production Engineering Review*, 10(3), p. 14.

Hellermann, n.d. *Cable tie guns – reliable, convenient, for long-term use*. [Online]

Available at: <https://www.hellermannntyton.co.uk/competences/cable-tie-guns>

[Accessed 03 03 2024].

HMRC, 2022. *Capital allowances for plant and machinery toolkit*. [Online]

Available at:

<https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fassets.publishing.service.gov.uk%2Fmedia%2F62e23adb8fa8f503312d7ca8%2FCapital-Allowances-for-Plant-and-Machinery-Toolkit-2022.odt&wdOrigin=BROWSELINK>

[Accessed 12 02 2024].

HSE, 2024. *Training and competence*. [Online]

Available at: <https://www.hse.gov.uk/work-equipment-machinery/training-competence.htm>

[Accessed 04 02 2024].

Industry 4.0: Challenges of Mechanical Engineering for (2021) Muji Setiyo.

Iphofen, R. & Kritikos, M., 2018. Regulating artificial intelligence and robotics: ethics by design.

CONTEMPORARY SOCIAL SCIENCE, 16(2).

Javaid, M. et al., 2022. Exploring impact and features of machine vision for progressive industry.

Sensors International 3, p. 11.

Javaid, M. et al., 2021. Significance of sensors for industry 4.0: Roles, capabilities, and applications.

Sensors International, p. 12.

Julia, H., Carpes, A. d. M. & Beuron, T. A., 2011. The DaimlerChrysler merger – a cultural mismatch?.

p. 9.

Justice, A. & Codreanu, C., 2022. *Product Development Starts with Proof of Concept*. [Online]

Available at: <https://www.machinedesign.com/community/guest-commentary/article/21242639/grid-connect-product-development-starts-with-proof-of-concept>

[Accessed 17 02 2024].

Knight, M., n.d. *Fully Automated: Which one is right for your manufacturing process?*. [Online]

Available at: <https://www.rnaautomation.com/insight/semi-automated-vs-fully-automated-which-one-is-right-for-your-manufacturing-process/#:~:text=However%2C%20semi%2Dautomated%20systems%20also,efficient%20than%20fully%20automated%20systems.>

[Accessed 14 02 2024].

Krishnan, S., Mathiyazhagan, K. & Raja Sreedharan, V., 2022. Developing a Hybrid Approach for Lean Six Sigma. *TRANSACTIONS ON ENGINEERING MANAGEMENT*, 69(6), p. 18.

KUKA, 2020. *Stronger, faster, more productive automation for the new normal*. [Online]
Available at: <https://www.kuka.com/-/media/kuka-corporate/countries/united-kingdom/documents/kuka-weareorange.pdf?rev=d717964b6025484697be0998bd4c6177&hash=BAB7D1E24E8CB7760868E6AA0623B278>

Kutz, M., 2017. *Applied plastic engineering hand book*. s.l.:Elsevier.

Lai, N. Y. G. et al., 2020. *Advanced Automation and Robotics for High Volume Labour-Intensive Manufacturing*, Ankara, Turkey: IEEE.

Langmann, R. & Michael, S., 2019. The PLC as a Smart Service in Industry 4.0. *Applied sciences*, p. 20.

Leibrandt, K., Cruz, L. d. & Bergeles, C., 2023. Designing Robots for Reachability and Dexterity:. *IEEE TRANSACTIONS ON ROBOTICS*, 39(4), p. 19.

Leng, J. et al., 2021. Digital twins-based smart manufacturing system design in Industry 4.0: A review. *Journal of manufacturing systems*, Volume 60, pp. 119-137.

Linkedin, 2023. *The UK Robotics Industry: August 2023 Update*. [Online]
Available at: <https://www.linkedin.com/pulse/uk-robotics-industry-august-2023-update-iconsys#:~:text=The%20UK%20lags%20most%20of,is%20below%20the%20world%20average.>
[Accessed 22 12 2023].

Liu, W. & Sun, Q., 2021. Research on a design method of pneumatic logic control system. *Measurement and control*, 54(5-6).

Lordan, G. & Neumark, D., 2018. People versus machines: The impact of minimum wages on automatable. *Labour Economics*, p. 39.

Maher, M., 2010. *The design/ development of automated programmable orientation tools for vibratory bowl feeders*, Waterford: s.n.

manufacturing, L., 2024. *How can you optimize assembly line layout for efficiency and safety?*. [Online]
Available at: <https://www.linkedin.com/advice/0/how-can-you-optimize-assembly-line-layout-efficiency>
[Accessed 04 02 2024].

Martino, N., 2023. *Striking a Balance: Ethical Considerations in Workplace Automation*. [Online]
Available at: <https://www.linkedin.com/pulse/striking-balance-ethical-considerations-workplace-nicolas-martino#:~:text=However%2C%20ethical%20concerns%20arise%20when,unrest%20if%20not%20managed%20properly.>
[Accessed 02 02 2024].

McKinsey, 2023. *What is digital-twin technology?*. [Online]
Available at: <https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-is-digital-twin-technology>
[Accessed 12 12 2023].

Morgantini, S., 2018. *Investment in Italy enhances offerings to hygiene market*. [Online]
Available at: <https://www.acelli.it/en/news-events/berry-completes-center-excellence-celli-nonwovens>
[Accessed 11 02 2024].

New Co extrusion adapter for Berry (2021) Reifenhäuser.

Olivio, T., 2021. *2021 Machinery & Equipment Review*. [Online]
Available at: https://www.nonwovens-industry.com/issues/2021-08-01/view_features/2021-machinery-equipment-review/
[Accessed 11 02 24].

Parker, M., n.d. *Using DMAIC for Project Management*. [Online]
Available at: <https://leansigmacorporation.com/using-dmaic-project-management/>
[Accessed 14 02 2024].

Payne, C. L. a. J., 2019. [Online]
Available at:
<https://orca.cardiff.ac.uk/id/eprint/125500/1/NTWE%20Lloyd%20and%20Payne%20pre-proofs.pdf>

Pérez, M., Carou, D. & Rubio, E. M. T. R., 2023. Current advances in additive manufacturing. *13th CIRP Conference on Intelligent Computation in Manufacturing Engineering*,, p. 6.

Plastics, h. o. f., n.d. *Hans Reifenhäuser*. [Online]
Available at: <https://plasticshof.org/members/hans-reifenhauser/>
[Accessed 11 02 2024].

Pris, M. et al., 2020. *Online Fault Detection*:. Rome, IEE, p. 5.

Qureshi, W., 2016. *HellermannTyton Cable Ties patent*. [Online]
Available at: <https://www.packagingnews.co.uk/news/paul-foot-hellermanntyton-cable-ties-patent-06-10-2016>
[Accessed 04 02 2024].

Reeco, n.d. *Vibratory Bowl Feeder*. [Online]
Available at: https://www.reeco.co.uk/cobot-products/vibratory-bowl-feeders/?gad_source=1&gclid=EAlaIQobChMI8ayzxpDYhAMVp5lQBh3qNAg7EAAYASAAEgJdFvD_BwE
[Accessed 03 03 2024].

Reifenhäuser, 2023. *Reifenhäuser Reicofil nonwoven lines*. [Online]
Available at: <https://reifenhauser.com/en/company/reifenhauser-group/reicofil>
[Accessed 11 02 2024].

research, n. i. o. e. a. s., 2021. *Press Release: Wales unemployment could rise above 6% by 2023, NIESR research shows*. [Online]
Available at: <https://www.niesr.ac.uk/news/press-release-wales-unemployment-could-rise-above-6-2023-niesr-research-shows>
[Accessed 10 01 2024].

rgbsi, n.d. *Types of Smart Sensors that Enable Industry 4.0*. [Online]
Available at: <https://blog.rgbsi.com/5-smart-sensors-enable-industry-4.0>
[Accessed 17 02 2024].

- robotics, I. f., 2021. [Online]
Available at: <https://ifr.org/robot-history>
- Robotics, S. a. a., 2018. *Machine Builders UK | What is a URS? Why is it important?*. [Online]
Available at: <https://sp-automation.co.uk/machine-builder-uk-why-is-it-important/>
[Accessed 13 02 2024].
- Roulet-Dubonnet, O., Sandoy, R. K. & Schultea, K. O., 2018. *Application of Design for Automated Assembly methods in the*. Nantes, Elsevier, p. 5.
- Sanja, K., 2023. *A definitive guide to proof of concept vs. prototype in product development*. [Online]
Available at: <https://codilime.com/blog/proof-of-concept-vs-prototype-in-product-development/>
[Accessed 17 02 2024].
- Shome, R., 2019. *Towards Robust Product Packing with a Minimalistic End-Effector*. Canada, IEE.
- statistics, O. f. n., 2023. *Employment, unemployment and economic inactivity in Rhondda Cynon Taf*. [Online]
Available at:
<https://www.ons.gov.uk/visualisations/labourmarketlocal/W06000016/#unemployment>
[Accessed 10 01 2024].
- Suleiman, Z. et al., 2022. Industry 4.0: Clustering of concepts and. *PRODUCTION & MANUFACTURING / REVIEW ARTICLE*, p. 27.
- Tan, S. Y. et al., 2019. *A Perspective on Education to Support Industry 4.0*. Kanzan, IEE, p. 6.
- tools, A., 2024. *Manufacturing costs definition*. [Online]
Available at: <https://www.accountingtools.com/articles/manufacturing-costs>
[Accessed 09 02 2024].
- Trinitium, 2023. *Key Factors for Choosing a Right System Integrator*. [Online]
Available at: https://www.linkedin.com/pulse/key-factors-choosing-right-system-integrator-trinitium?trk=article-ssr-frontend-pulse_more-articles_related-content-card
[Accessed 16 02 2024].
- Tubex, 2023. *About Tubex*. [Online]
Available at: <https://tubex.com/about/>
[Accessed 09 01 2024].
- Tucker, J., N/a. *CREATIVE ENTREPRENEURS: THE STORY BEHIND INNOCENT DRINKS*. [Online]
Available at: <https://www.headspacegroup.co.uk/creative-entrepreneurs-the-story-behind-innocent-drinks/>
[Accessed 07 01 2024].
- Universal, R., 2019. *HOW TO CHOOSE THE BEST ROBOTIC GRIPPER FOR YOUR WORK?*. [Online]
Available at: <https://www.universal-robots.com/fi/blogi/how-to-choose-the-best-robotic-gripper-for-your-work/>
[Accessed 03 03 2024].
- Wang, Z.-H., 2023. A Novel Soft Sensor Approach of Polymer Process for Resin Monitoring Based on Melt Pressure Spectrum. *IEE Sensors journal*, 23(15), p. 8.

Worksoft, n.d. *ASUG Survey Reports Why Users Are Hesitant*. [Online]
Available at: <https://www.worksoft.com/corporate-blog/5-common-barriers-to-automation-how-to-solve-them#:~:text=Understanding%20what%20to%20automate%20can,routine%2C%20simple%20tasks%20to%20automate>.

Worster, A., Weirich, T. R. & Andera, F., 2013. Overcoming the Challenge of System Integrators.. *The Journal of Corporate Accounting & Finance*, July - August(1), pp. 15 - 23.