

Introduction to Industry 4.0

Assignment 2 – Essay

MSc International Innovation Management

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Introduction

At SSGB, we have an analogue final assembly line with a small integration of a digital factory with the intention of implementing Industry 4.0. The majority of data is collected through human interaction, which is then converted into excel and delivered in powerpoint presentations. Furthermore, for the product build, we have planning phases that are not linked to an ERP system, and the build itself is still limited to paper rev controlled working instructions.

The above affects the facility's efficiency in terms of product release, NVA (non value added time) is not fully understood this is critical to driving the factory into a clear phase where understanding this NVA will support the growth of the business, allowing profit and customer satisfaction to grow.

As we continue to use this NVA system, we will inevitably increase the risk to the overall quality of our management system for traceability, but we will also open the door to internal and external audit findings, some of which may result in the removal or suspension of licenses or approvals.

We misled the operational team about the need for and importance of Industry 4.0 due to a lack of engagement. The current system works according to the operational frontline, and there is no reason to change it. With this culture embedded in the day-to-day operations change can become contentious and difficult to implement.

Incorporating elements of Industry 4.0 into the business will change not only working methods but also workplace culture. A digital factory allows for control over the data collected, it can also enable IoT to provide proven algorithms that can be used to define where issues exist allowing for the implementation of new methods. Lessons learned can also be implemented and in most cases a version of APQP can be implemented in this environment, pushing the business to be proactive rather than reactive.

IoT can support the increased need for data collection to validate a business's direction, as well as the methods, tools, and structure in place to support it. When collecting data an integrated seamless system supports the analysis phase for improvements, having all of the data from cradle to grave allows actions to be created and ownership given to the appropriate business team for containment and corrective actions.

As we begin to integrate Industry 4.0 into the factory's build cycle, we must also consider the benefits that may accrue outside of the sold product. This will allow us to quickly support and close down customer escapes or in-service issues, as well as support any repair work. With this information stored in a centralised system, we can use it to improve our customer satisfaction and overall business reputation by incorporating these flaws into future designs.

As previously stated in the current analogue state the business can only be reactive, there is limited data available, and if any is available it is heavily analysed via human interaction, which can introduce defects resulting in the wrong actions being taken. With the implementation of Industry 4.0 and the construction of a digital factory into the business all areas will become more reactive, assisting in making instance decisions that will internally provide corrective actions instantly to remove the blocker in place.

The main body topics will look at the below,

- Integration of industry 4.0 into planning – Loading a product onto an assembly line with its required parts kit is difficult under the current planning format. This is due to part allocation

that is not in sync with the base structures, which means that several structures are stuck in operations and are not progressing. Once this time is lost, we have to make up for it by working overtime or adding shift work, which comes at a high cost.

- Integration of industry 4.0 into the manufacture line – The operational working instructions on the build line are in paper format, which limits updates to either drawing changes, customer requirements, tooling changes, or overall part changes via revision. There are over 500 pages spread across 12 operational stations and several copies per line station, which means that if an amendment is required all copies must be acquired, production must be stopped, files must be updated, and new copies must be printed before production can resume without errors causing quality escapes.
- Integration of industry 4.0 to support a data analysis tool for non-value added elements – When analysing data we must first collect the data into a single point. Again, human interaction is the current method any defects discovered during inspections are recorded on paper and then reworked to the correct standard. Once this is completed it is a reactive process in which data is transferred into Excel to pareto the defects in order to create an action tracker to permanently correct the top defects. When using this format we frequently live with the problem and accept that rework is an unavoidable part of the build process.

To move forward and sustain improvements, we must first comprehend the pillars of Industry 4.0, (Kidwai, 2021) sets out the below as the key nine pillars of industry 4.0,

- Big Data & Analytics
- Autonomous Robots
- Simulation / Digital Twins
- Industrial Internet of Things (IIoT)
- Augmented Reality
- Cybersecurity
- Cloud Computing
- Horizontal & Vertical System Integration

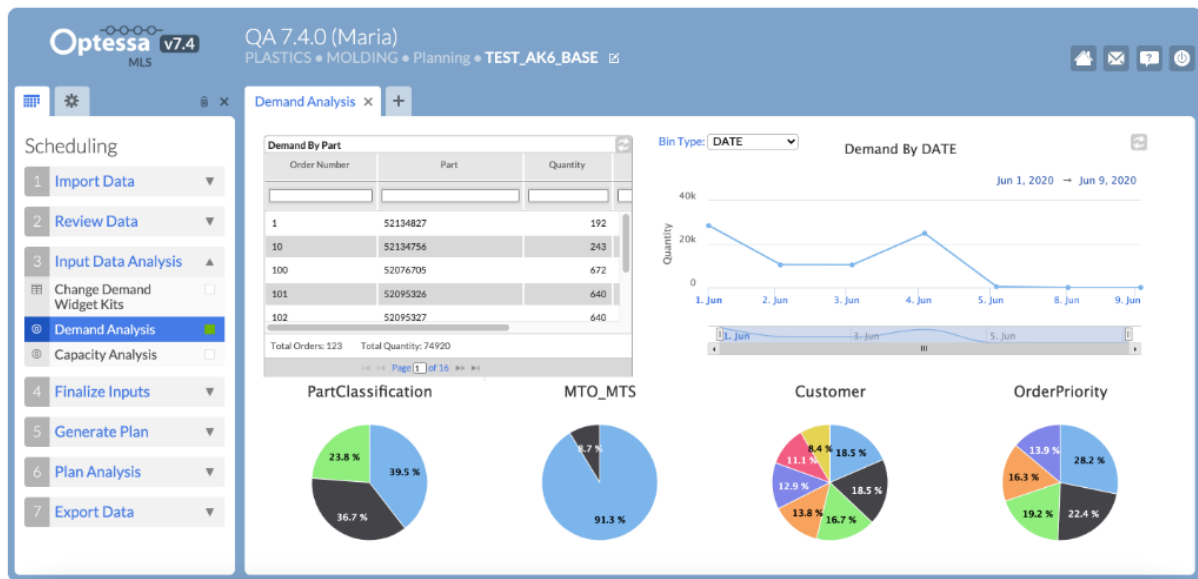
We can decide which elements to implement in the business to achieve the most effective results that are aligned with our overall goals and targets once we understand the above. Digital simulations such as the one shown below from (TWI, 2023), allow us to understand how new technologies will integrate with one another, as one phase may provide a benefit while another may cause bottlenecks or failures later in the process.



Main Content

Planning

When we investigate what changes Industry 4.0 can bring to the business, we quickly discover how it improves the flow from start to finish. Product loading, parts, work instructions, builds, inspection gates, release, and dispatch all become more precise and in line with customer delivery dates. Improvements in logistics, such as bar-coding and RFID tags, allow us to understand quantity and location of items, which are all automatically logged into a digital system. Build quality can be improved and delivery dates can be met. As we look at the first phase of planning, (Optessa, 2018) examines the evolution of planning and scheduling up to 4.0. With the impact of new automated systems such as the Optessa MLSV7+, any changes in the build process, availability of parts, process, or people can be re-aligned, and new recovery options will be provided. At first the system can support elements such as head count, working hours, turnaround times, and when items such as dispatch facilities should be reserved. This data is now calculated in a single location rather than by multiple humans, which eliminates the elements of lack of communication, mistakes, and overhead costs.



The image above provided by (Advice, 2023), depicts how a dashboard database might look with all of the data in one place and live. In our industry we can connect IoT software to this dashboard to collect data from our kitting process and base structure alignment. Kits and base structures can be barcoded or labelled with RFID tags and once the tags have been scanned in their respective areas, we can determine how long it will take for the two to join on our workshop for an allowable start time. This data merger will also show whether we need to speed up or slow down in either area to avoid a bottleneck.

As this data provides the foundation for seamlessly integrating both kits and base structures, we can begin to consider improvements in other areas. Human interaction physically picking parts for kitting has always been a part of the kitting area. This is where robotics has been introduced in many companies, (Koetsier, 2022) reviews in depth why robots are introduced and how some companies can in-tern reduce costs to the point where deliveries are free to the purchaser.

Amazon introduced Fanuc 6-axis robots into their distribution center, these kit all delivery products, the benefits listed below were quickly discovered which not only improved the efficiency over human interaction but also reduced costs.

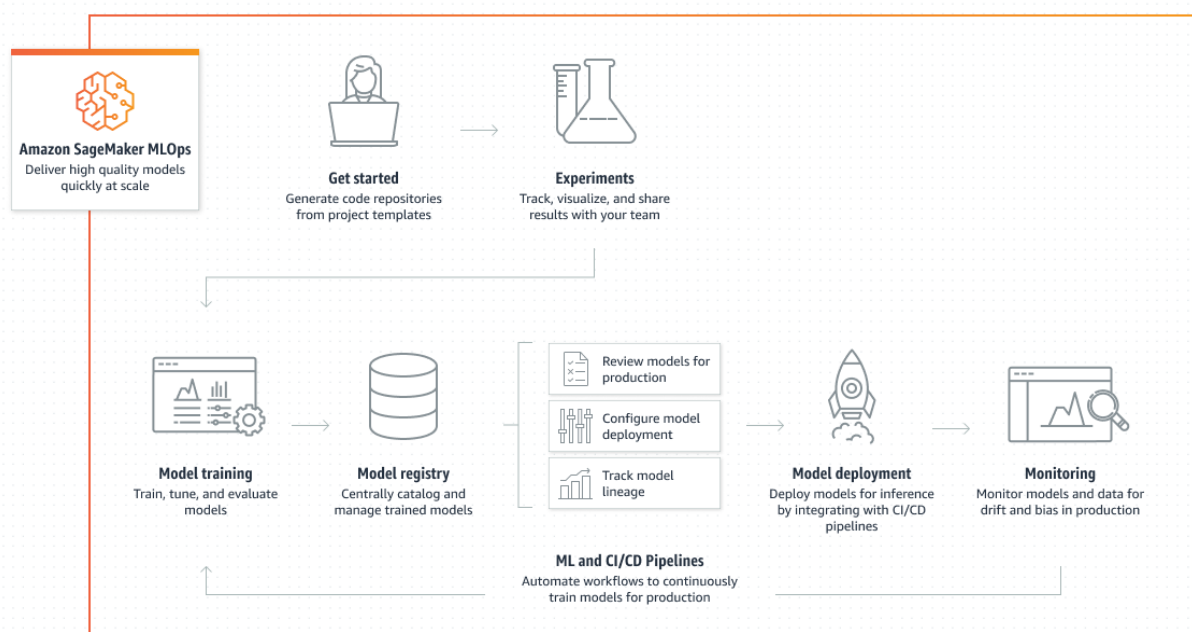
- Double / Tripled the picking / kitting count
- Reduced human traffic by 75 to 80%
- Ability to lift objects in excess of 1200kg
- Reduce the training time, resources – people and room space
- Reduction in human injuries

- Ability to run 24 hour shifts
- Reduction in breaktimes
- Reduction in facility cost i.e heating, lighting general amenities
- Increase in skill set for robotic programing operators



With the advent of robotics software can now be purchased off the shelf and supported by packages, or it can be developed in-house. Amazon chose to develop its own software known as the Amazon SageMaker. Below (SageMaker, 2023) is an overview of ML (machine learning) models that must be programmed for robots to perform effective work, such as indicating the location of recharge points or multiple picking points.

Upskilling current employees is the ideal way to provide a culture within the workplace where robots are not here to take over but opportunities to develop skill sets are, throughout the entire business structure engineers and specialists will be required to support the robot integration.



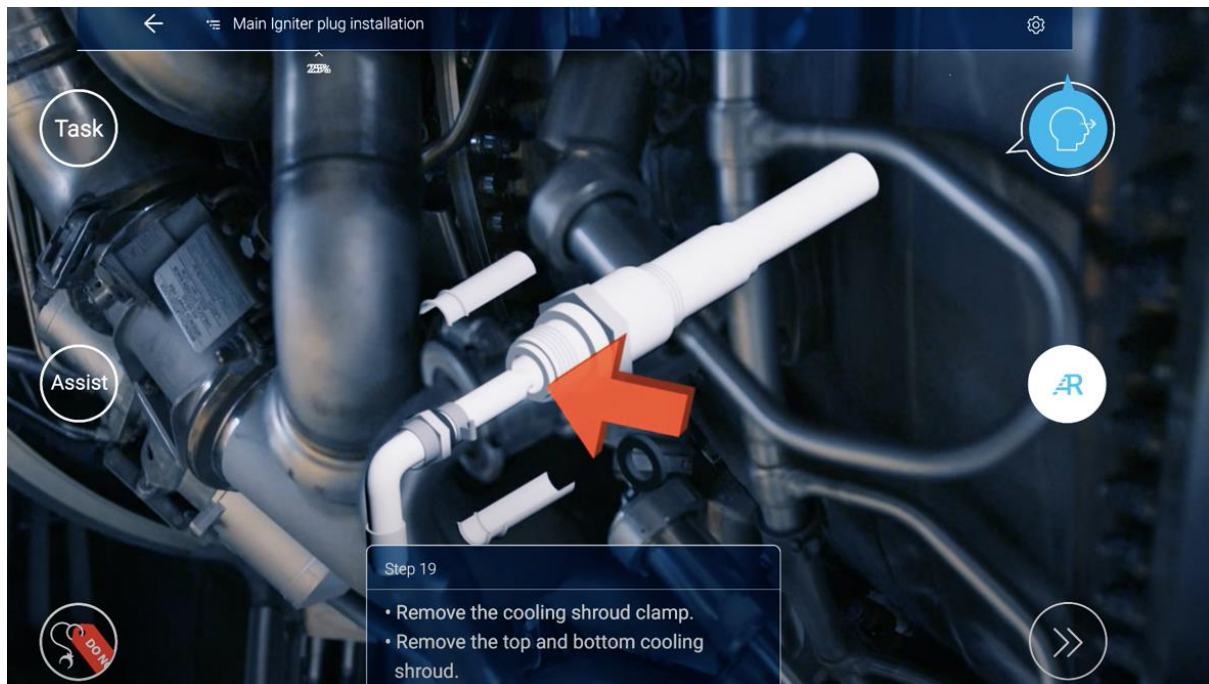
Manufacturing Build

We need to implement Industry 4.0 during the operational build process to eliminate the need for paperwork instructions. As previously stated, not only are amendments difficult to complete but overall communication with an operator is poor. The incorporation of a digital factory allows the operator to have a clear understanding of how an assembly is completed. AR (augmented reality) is a technique that overlays virtual components on top of a real-world background. A model could be uploaded and parts aligned for assembly by an operator. The HoloLens2 accomplishes this through a headset in which a visual image is overlaid, as shown below where it is used at Airbus.



(Connectar, 2015) reviews how the development of this AR can assist an operator, the below image of an operation step also integrates much more information, this includes,

- The ability to see any safety data i.e high voltage or mind the step
- Provides additional details if require for the operation
- The ability to call on the team for assistance, possibly a senior operator
- An engineer call button, for support where the operation can not be carried out with the current information



In order to improve safety, quality, and security throughout the operational build (HoloLens, 2020) provides the benefits seen from a business standpoint, these are in collaboration with Airbus. The increase in daily efficiency is more than 30%, and the reduction in errors is more than 50%, this is how an increase in quality leads to an increase in safety. The data provided to the HoloLens2 operator can be used to validate that the work performed is of the required quality and that no tasks are left unfinished. The image below depicts a final aircraft sign off in which all the working instructions can be viewed in a merged state where scanning the aircraft would be completely green.



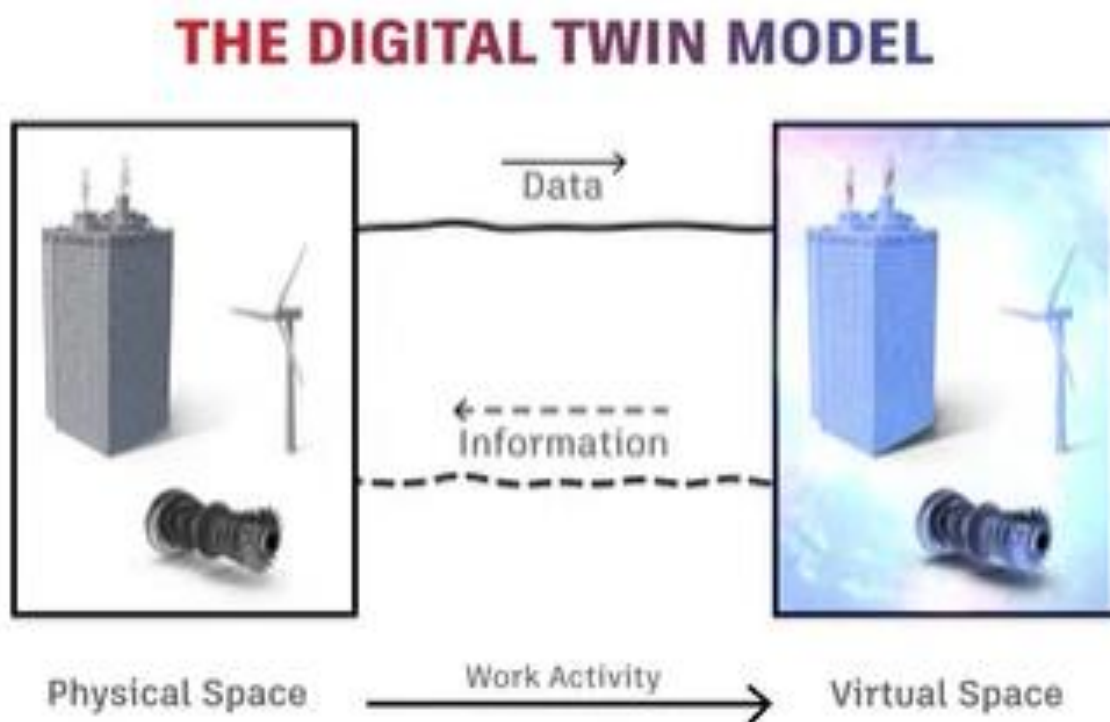
This integration of technology within our manufacturing line would exacerbate the problems we are currently experiencing in an analogue state. All parts of the displayed working instructions would be up to date, including drawings, model displays, and part numbers all at the latest revision.

Furthermore, updates would be instant and quick, eliminating the need for operators to rely on outdated documents that may contain incorrect standards and have the potential to cause quality escapes affecting the customer. The current staff who created these amendments and manually control these paper working instructions could now potentially be redeployed into the integration team to bring in the AR technology, which as with Amazon would support a positive culture change rather than a negative one.

As with most advanced technologies they are not cheap the Hololens 2 costs slightly more than 3500 euros per unit, so what alternatives can be used to provide benefits? Additive manufacturing, or 3D printing, is significantly less expensive, but what role could it play? This cannot carry out the change of working instructions into a digital format, but it can help with validation processes during the build. Low-cost molds can be placed over finished work to validate positions, depths, component sizes, and overall go/no-go gauges. (Goldsberry, 2020) provides a case study on how 3D printing is transforming the industry, covering five topics, one of which is validation and advanced measurements. Fused deposition modelling (FDM) is one method discussed, with this process multi-functional tools that fit onto a datum point and marry up against other features can be created. If the features do not match, it means that something in the operational build is incorrect and, in some cases will not fit into the adjoining part of the build. Because these 3D printed parts are made of plastic they are less likely to cause damage when checking, as opposed to steel checking tools, which can cause damage due to operator difficulty due to weight. When these go/no-go gauges are used, we can begin to foster a culture of quality assurance / right first time rather than quality control, where in-depth inspections are performed at the final build point. We can monitor the defect reduction as these 3D parts are introduced into the build for verification, once this is at an acceptable level we can reduce the inspection point to a simple certification check for release purposes.

Prior to investing in either AR technology or 3D printing, we can look to use a digital twin to see what the benefits are and if we inadvertently cause other issues such as bottlenecks. A digital twin would be providing a direct replica of the assembly line but in a virtual world. The twin would be linked to the assembly line via monitors, and in the case of AR the Hololens2 would update the twin via IoT software. When we make changes to working instructions we use the twin to see if the changes still meet customer standards or any external regulations. With the amendments approved, the twin would provide data on whether this change improved efficiency or quality. In comparison to 3D inspection gauges, this would follow a similar pattern in that we would be able to understand how frequently the gauges are used and if they are worn by installing sensors in the receipting part of the gauge storage holders. This would be one part of letting us know if we were going to be outside of any tolerance band, preventing quality escapes from being passed on to a customer. A digital twin

can be used for much more than the two examples given above, it can be used to develop a part, system, or process. (Resources, 2021) describes how this technology began in the 1960s, when NASA used mirror technology to aid in testing solutions on the replica prior to implementation. Michael Grieves took another step forward in 2002 by introducing the digital twin with a life cycle, as described below this is where data and information work between physical and virtual space.

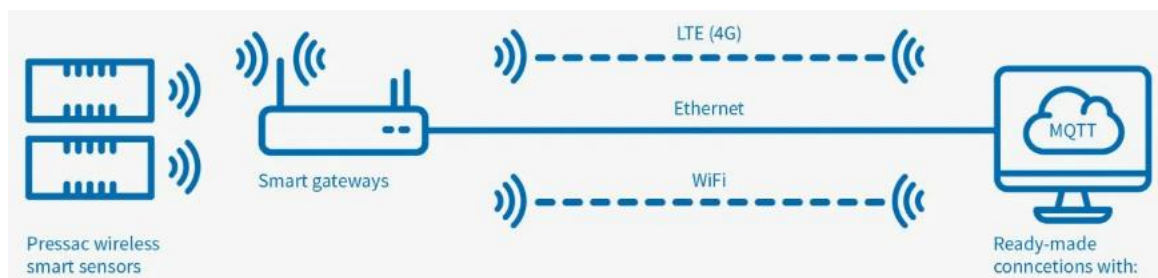


The introduction of AR can use this method of a twin within our business of improving the working instructions to a digital format. Furthermore, if we use the HoloLens2, we can integrate sensors within to ensure we meet the correct standards, for example, the talk setting on a ground stud. Not only would we understand the impact if we changed a value, i.e. would it fail or retain for longer, but we would also understand the fatigue potential in the tooling being used, and when it would require refurbishment. The twin would retain this information and always would be slightly ahead of reality, it would also give us a new understanding of what cost, efficiency and headcount would look like.

Data Analysis

Our business relies heavily on manual intervention to enter all data into access databases or excel spreadsheets, which are then converted into pivot charts. Industry 4.0 is a long way off and will necessitate significant investment to provide a digital level in which data is automatically inputted and logged in a central location.

(Monitoring, 2019) describes how sensors can measure a variety of parameters the key is how the data is collected and how we can easily analyze it. Smart sensors could be used in our assembly process to understand product movement and completion points. Once we understand this, we can examine efficiency times, adjust head counts, and possibly merge operations to eliminate bottlenecks. The extraction of information from sensors can be difficult due to the language (protocols) used by the sensors and the receiver (possibly a cloud) or the location of the sensor. Most sensors are wireless, and without a short line of sight connecting to a cloud would require a lot of power, implying that the sensor would not last a full working day without being recharged. Gateways are the most common way to connect to a cloud that is located at a distance, these gateways aim to bridge the gap. The model below shows how the smart sensors connect to the gateway, which is connected to the cloud. The information is converted by the gateway into the JSON protocol. The cloud can then connect to the appropriate software package, resulting in an instant digital factory.



With the integration of the above, we can create a culture in which all operational areas are responsible for their own improvements and a reduction in non-value added time. The data collection has been displayed below into parts, processes, and people NVA. Furthermore, the live real time allows for the formation of a team to assist in the resolution of issues that arise during the operational build. This can then be fed into the digital twin for future enhancements, and the IoT can run its algorithms to suggest new benefits to implement.



When comparing IoT and IIoT, we must consider what will be most beneficial to our business. The Internet of Things (IoT) and the Industrial Internet of Things (IIoT) share some similarities but differ. (Mulchandani, 2020) highlights the differences that will dictate what would be best for the business,

- IoT looks at connections to robots & machines where IIoT also looks at all manufacturing process also the alignment to a facility and how it is combined
- IIoT has the connection to precise sensitive sensors that can be costly, however IoT is normally at a smaller level with simple connections via wireless devices.
- IIoT deals with large scale industries where as IoT is used in more local environments
- IoT can be programed off site, IIoT can be either used in both site or off site. (Off site is not recommended as changes can cause damage to the current set-up)
- IIoT mainly works with medium to high data volumes, IoT handles excessive amounts of data.
- IIoT works with digital twins with a long life cycle of programs, IoT has a short product life cycle and does not support the memory capacity without additional investment.
- IIoT is deemed a reliable system where as an IoT system is less reliably.

Cost must be considered when implementing industry 4.0 technology, our company is not a start-up so adaptation will be necessary. (Kelber, 2020) examines how we must understand how much current downtime costs us, as well as the value per hour in specific areas. Once this is established, a valid business case can be developed in which a break even point is reached and the benefits, as well as financial savings, are understood. As this is completed and integration is implemented, it is critical that all stakeholders are kept up to date and have a clear picture of the development's progress. Again, culture change is critical during this period, and participation from all team members is required. The goal is not to isolate individuals, but to work with them so they understand that these improvements require support and are not intended to remove them from the business.

Conclusion

The pillars of Industry 4.0 provide clear guidance on what is required to sustain a business in the current industrial evolution. The key points are questioned in this essay so that we can understand how, when, and what are the best tools to support our business. The areas reviewed during planning, manufacturing build, and data analysis, as well as their subsections, will require detailed support in determining which process requires development first. Not all parts of the business would undergo changes at the same time, causing confusion and potential production line stoppages.

We have looked at some hardware and software costs in this essay, the AR system for the operational line would be significant. If the business requires assistance in funding these new technological

advancements, government assistance is available. (GOV.UK, 2020) lays out the foundations for how this can be accomplished depending on what technology is introduced into the business and how that can affect new job creation in the local area. An amount of up to £300 million can be requested if the correct justification is provided. Within this justification / business case, elements such as salary band incrimination for retention or local recruitment must be included.

Along with the aforementioned, the overall cultural environment must be reviewed, many businesses conduct baseline assessments to determine where they stand. To complete this activity, other businesses have used what are known as champions. With the goal of shifting from reactive to proactive again, this can help support which areas to look at first. (Mellssa A.Schilling, 2019) examines how current employees can be used as champions to engage the operational team in changes to the current flow. With these champions, there is a single point of contact for issues that require escalation, as well as a single thread of communication that prevents messages from being lost in translation. Champions who were previously part of the operational team are more likely to get engagement and extract information at a deeper level if they are chosen correctly. Collaboration in this manner contributes to the development of a positive culture, as well as the introduction of targets such as KPIs, which drive further improvements to the flow process.

There are several benefits to industry 4.0, most notably moving from a reactive to a proactive state, but that is not the end. The future of industry 4.0 is to integrate all new technology, once this is completed, the next phase proposed by (Salgado, 2022) is to become predictive. This is the stage at which data is thoroughly analyzed and patterns emerge, from this we can almost be ahead of the game. In a predictive environment, this technology is knocking on the door of Industry 5.0, where autonomy and AI advance efficiency, reduce risks, and increase safety and quality.

Industry 5.0 has not yet reached the industrial level, but that does not mean we should be unaware of it. Industry 5.0 is discussed by (Kraaijenbrink, 2022) in the sense that the shift from 4.0 is to focus on societal values and promote wellbeing. When aligned to basic work scopes, the reliance on human interaction appears to be reduced, if automated machines can perform multiple tasks or complex tasks more efficiently, these should be adopted. AI-enabled new technology and evolving robotics would be able to make instant decisions that are faster and more effective than human interaction. This is not to say that, as in fiction, robots will replace all human interaction rather as previously discussed, this provides opportunities to upskill the workforce in programming and maintaining these newly developed technologies. There are also environmental factors that support Industry 5.0, the vision of this industry is to significantly reduce the use of fossil fuels, which contribute significantly to global warming. Because robots do not require human vision, industry 5.0 enters a light-out mode to

achieve these environmental factors. All of the amenities that humans require can be removed, including lighting, heating, toilets, and food services. This means that the floor space within a business can now be optimized with new layouts for additional product, with an input and output of materials serving as the only point of interaction for a human. With the exception of planned maintenance for the lines and robots, the only other downtime would be when loading material.

Overall, if we do not embrace new technologies and incorporate them into our operations we will fail. Customers will visit multiple sites when looking for contacts to award new work, other business providing confidence will cause our company to lose its competitive edge. These customers seek that competitive advantage that provides assurance that deliveries will be made on time and to the required quality standard. Limited risks within the full flow of new programmes will win contracts and promote incremental innovation as industry 4.0 is further integrated into the business.

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