

Industry 4.0 Manufacturing Technologies and Manufacturing Execution System.

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Assignment 1 Written Report

Author Note. Contents of this paper are linked to a live Safran project

MADE Industry 4 Wales (I4W)

Summary

The term “Industry 4.0” was first introduced in 2011 (Springer, 2019). Businesses, manufacturing operating within this current fourth industrial revolution today as opposed the first industrial revolution, simplistically put would be like comparing a horse and cart to a Ferrari Tesdarossa.

Industry 4.0 is an immergence of collective innovation and technology constantly accelerating. Whether intentionally or not and in many cases, businesses are utilising Industry 4.0 on literally and an hourly basis in all probability at a minimum, but most likely to be minute by minute or more.

As part of this Industry 4.0 made up of the Internet of Things, Devices, Equipment, Machines, Robots and Cobots, Artificial Intelligence and more, there are also many facettted software applications used collectively in businesses and industries to enable and ensure smooth running of business operations. A Manufacturing Execution System (MES) is one. What is its role? What are its components? How does it function? What are the benefits and impacts? These are some of the topic areas that this paper will explore and looks at.

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Introduction

Socially over the last 30 plus years, the internet has been with us, for many, it is now a lifeblood. Today it is incomparable to its humble beginnings. During these early formative years for most it was dial up access, slow, clunky and limited in just about every way, yet it was a marvelous thing of wonder and awe. Stories of what was to come, perception, vision and speculation of its potential, were by large taken with a pinch of salt.

However, the pace at which it transforms business, social and working life can only limited by imagination. A simple task, such as increasing or decreasing the temperature in the home. Today, this can be actioned by a spoken command or with the gesture of a fingertip on many device. A mobile phone or mobile communication in your car, tablet or laptop, can release an unbroken chain of IoT (Internet of Things) events to conduct the task, that if explained fully and in depth would equate to library full of books. The overall extent and depth of IIoT (Industrial Internet of Things) is breath taking and a phenomenal extent covering; aspects of; banking, sales, procurement, logistics, manufacturing, medical, security, design, research and development and many more, it is fair to say that any activity done during the day uses and interacts with IIoT. How all this comes together and interacts is clearly documented by the likes of; (Gilchrist, 2016), (Goldratt, 2012), (Marshall, Larry, 2016), (Schwab, 2016) and (Stallings, 2016).

Is it business commerce, retail, manufacturing or society driving the trend? Probably all of them, unquestionably they are in one form or another or to a lesser or greater degree. Engaging in what is known today as Industry 4.0, to quote Daniel Burrus is “The general definition of Industry 4.0 is the rise of digital industrial technology... Industry 4.0 transformations allow us to work alongside machines in new, highly productive ways”.

SAFRAN Seats GB is changing significant many digital changes already are in place, in 2021 it introduced Convergence Plus software. In 2022 the decision made to continue change introducing new ERP to M3 software as the next phase of strategy for the business.

The Manufacturing Unit (MU) is core to the business providing machined components for; Aftermarket, New Product Development and Introduction (NPD, NPI) and support for strategic purchasing. Updating of equipment and systems to accommodate the changes required. As a continuation of this transition, the Manufacturing Unit being the current phase is now readying itself for integration and introduction of; 5 Axis machining, Digital Twins of machines, Tool Management System software (TMS), Manufacturing Execution Systems software (MES) along with other manufacturing IoT devices. The aim and challenge of having a fully functioning system in place producing components by the end of 2022. To assist in making the right decisions and choices SAFARN Seats GB is working collectively with University of Wales Trinity St David (UWSTD), utilising resources and support provided through the Smart Digital Accelerator program and the Welsh Government Assembly (WAG).

Components found in Advanced Manufacturing

What is this new wondrous technology found in industry 4.0?

These technological progressions collectively allow us to do shopping, travelling, entertaining, socially interacting or working, banking etc. as well as business and manufacturing it is virtually impossible to escape technology. Almost everything, touched, seen or heard today inevitably is completely interconnected to labyrinth of communication channels, hardwired or by wireless means.

The following identify and categorises the '**Industrial Internet of Things**' (IIoT).

- i) **Big data and Artificial Intelligence analytics.** Collected data from many varied sources, devices, item of equipment, software and computer systems. This data in turn is analysed artificially intelligence and learning applied to the data in real time to improve speed up the making of decisions in research & development, asset & logistic management, supply chain or purchasing.
- ii) **Horizontal and vertical integration.** Horizontal, the production areas either singular or multiple and the supply chain. Vertical is where all the layers of a business are linked and data transfers seamlessly from top to bottom and back, such as quality, design, engineering, industrialisation and any other departments, freely sharing data and knowledge.
- iii) **Cloud computing.** This gives business the means to the end for innovation, cost efficiencies, storage, speed are just a few of the elements for enabling; the internet of things, machine learning, artificial intelligence
- iv) **Augmented reality.** Is a game changer for training, technical support, maintenance, servicing and is still an emerging technology, this is the use of mobile device, visualization, through means of smart glasses that allows the wearer to see real time digital data and/or information overlaid on the physical thing when being looked at, instruction, guidance, model overlay and more.
- v) **Industrial Internet of Things (IIoT).** Also sometimes referred to as the Internet of Things. These are the physical things, machines, devices, robots, equipment sensors (providing real time data). These help to run product more smoothly, modify or design parts rapidly, reduce or prevent equipment downtime, track inventory and many other functions.
- vi) **Additive manufacturing 3D printing.** This technology allows for many types of media to be printed, plastics; soft or rigid, silicones and metals. While able to produces extremely complex components that would be impossible to make conventionally, currently it is a lengthy process. While there are many benefits attainable through this process, it does not lend itself at present even to cost effective low volume production but will surely change as technology progresses.

- vii) **Autonomous robots.** Not strictly something new. Nevertheless, with the additional connectivity with new modern technology, cameras, laser positioning, sensors, machine learning and co-bots (human movement taught). These can now conduct far more complex and delicate tasks being equipped with artificial intelligence and state of the art software.
- viii) **Simulation/Digital twins.** This is a digital model twin of an actual piece of equipment or machine etc. It allows virtual simulation of real equipment, machine, product and process that can be analysis giving accurate data for improvement or correction prior to actual real manufacture.
- ix) **Cyber security.** The greater the innovation, the greater the development and thus the greater demand for connectivity and exchange of big data, the greater the risk of threat to cyber-attack, compromise of critical data or production processes. Innovations such as Blockchain a smart encryption system that grows and sequentially re-encrypt, allow businesses to automate detection of potential threats from cyber-attack, reducing risk of data theft or escape of data exchange trough networks.
(Polestar, 2021).

Figure 1. An illustration of types of digital technologies

Industry 4.0 framework and contributing digital technologies

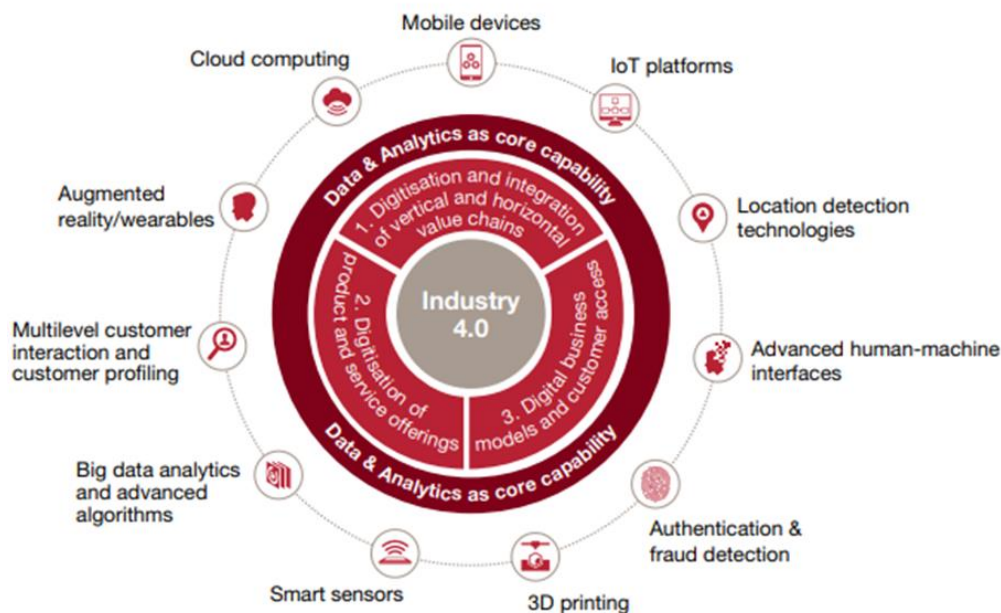


Figure1. (Geissbauer, et al., 2016)

Enterprise Resources Planning (ERP) & Manufacturing Execution Systems (MES)

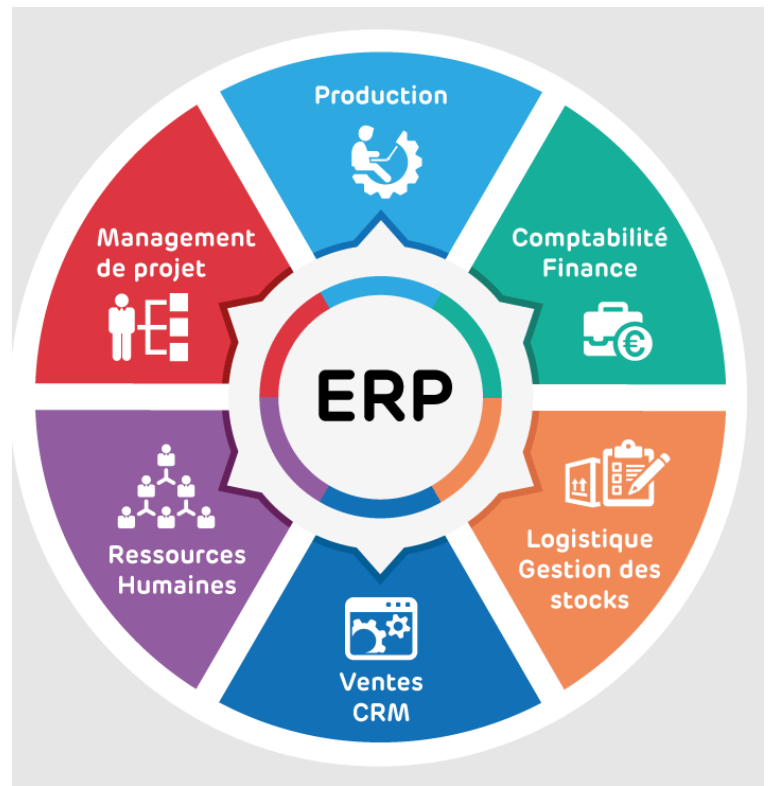
A Manufacturing Execution System (MES) can standalone. However, for manufacturing business especially to maximize, efficiency, control and potential it is better when paired, linked to and used in conjunction with an Enterprise Resource Planning (ERP) software application, working collaboratively constantly exchanging information streamline operations across the business. *Figure 2.*



Figure 2 (ResearchGate, n.d.)

Enterprise Resource Planning (ERP)

What is an ERP? ERP software manages modules within a database of the different elements/departments found within the business. Typically these that are all fundamental to the functioning of any business whether they be a global corporate company or a small, medium enterprises (SME's) they all need to control and understand what is going on in business that are critical to success. These as such are employees through human resources, finances and accounting, supplies and distribution, design and projects, production and inventory or E-commerce, sales and invoicing, as illustrated in the example of *Figure 3.*Figure 3 (Choisirmon, n.d.)



Manufacturing Execution System (MES)

An MES is used and typically found in the manufacturing of goods from raw materials and/or bought components to finished goods/products. It allows businesses to document, monitor, track and control the manufacturing processes. The MES links directly to 'Production' in figure 2 on the previous page. It provides live manufacturing data that can be analysed autonomously. The interaction between the applications provides robust business complete data enabling various departments to fully, understand the exact status of production compared to demand at any given moment in time. (SAP, n.d.). The typical data that is found within a Manufacturing Enterprise System is critical for controlling and feeding back information that could mean the difference between success or failure of a business. MES features below identified by SAP Insights are;

Core MES features

In 1997, the [Manufacturing Enterprise Solutions Association International](#), or MESA, defined the 11 core manufacturing execution system functions. Although the MESA-11 model has evolved over time, those original 11 core functions provide the base to run almost any type of plant and are integral to today's manufacturing execution systems. They are:

- **Resource allocation and status:** Use real-time data to track and analyze the status of resources, including machines, materials, and labor, to make allocation adjustments.
- **Operations/detailed scheduling:** Optimize performance by scheduling, timing, and sequencing activities based on priorities and resource capacity.
- **Dispatching production units:** Manage production data flow in real time to easily make quick, calculated adjustments in production dispatching.
- **Document control:** Manage and distribute documents – including work instructions, drawings, standard operating procedures, batch records, and more – so they're accessible and editable.
- **Data collection and acquisition:** Track and collect real-time data about processes, materials, and operations and use it to make better decisions and increase efficiency.
- **Labor management:** Track worker schedules, qualifications, and authorizations to optimize labor management with less investment of time and resources from management.
- **Quality management:** Track quality deviations and exceptions for improved quality control management and documentation.
- **Process management:** Manage the entire production process from order release to finished goods. Gain insight into bottlenecks and points that affect quality while creating full production traceability.
- **Maintenance management:** Use data from your MES to identify potential equipment issues before they happen and adjust equipment, tool, and machine maintenance schedules to reduce downtime and increase efficiency.
- **Product tracking and genealogy:** Track the progress of your products and their genealogy for informed decision-making. Having the data of a product's full history is extremely useful for manufacturers who must comply with government or industry regulations.
- **Performance analysis:** Compare results and goals to identify strengths and weaknesses in the overall process and use that data to make systems more efficient.

(SAP, n.d.)

Figure 4 and figure 5. Example of MES

MAZAK ISMART FACTORY™ SOLUTION

Data collection, utilization and analysis

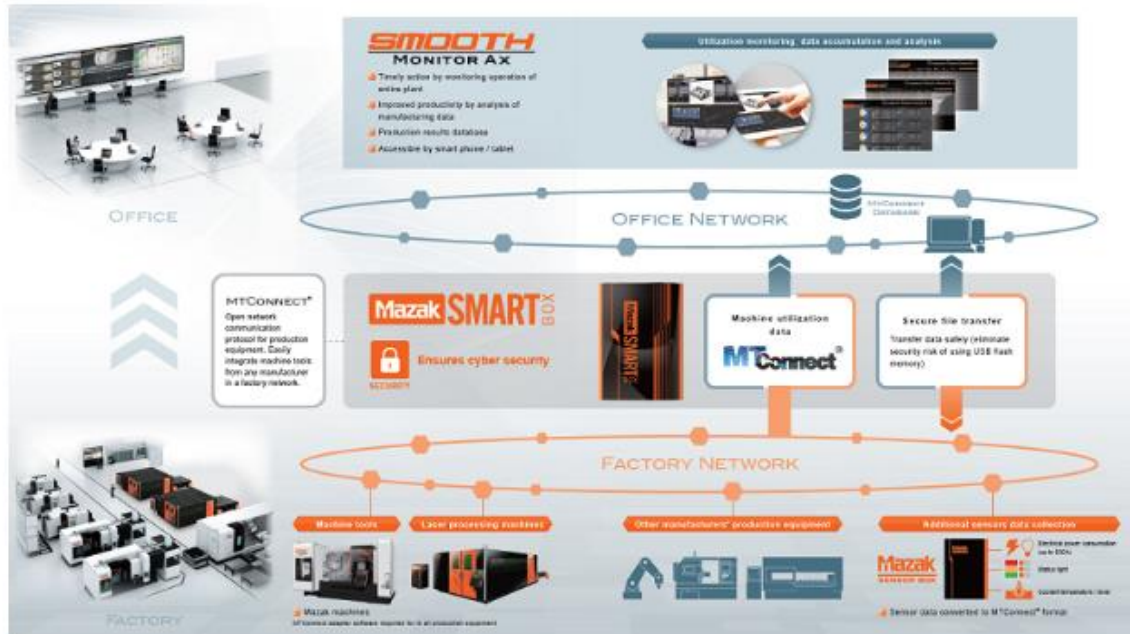


Figure 4. (Mazak, n.d.)

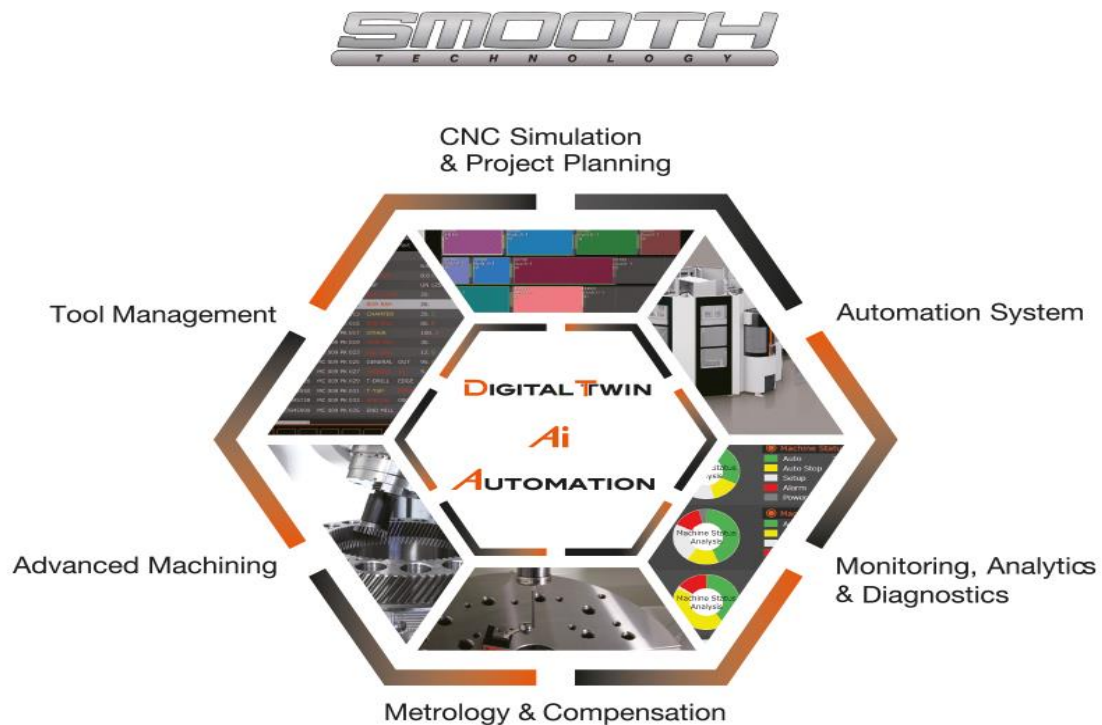


Figure 5. (Mazak, n.d.)

Where there is no MES in place the impacts and wastes are many, such as, manual micro-management and planning, walls covered in recovery plans, pages and pages of spreadsheet reports, slow progression and output late delivery of raw material and consequentially late deliveries to customers to highlight but a few. All extremely inefficient and extremely frustrating people for staff and customers,

Before making a Digital transformation and an introduction of an MES these are some considerations.

- 1) Implement thorough extensive lean activities across all aspects of the business.
- 2) The process as it stands today is not always completely relevant to the requirement and may oppose the principles of 'Industry 4.0'.
- 3) Fully understand processes and procedures for the business that allows for non-restrictive manufacture of a product or products. Ensure that all blockers are identified that exist in the process currently in use and removed.
- 4) Fully identify exactly what critical data requirements and pathways are for the business needs that are required. Verify processes and procedures that the business operations work to, re-check to ensure everything present is exact and correct with, invoke amendments and add them, update accordingly.
- 5) Manage the change; include people, processes and procedure. This will ensure that robust, streamlined, lean processes and procedures applicable to the requirement developed and put in place.
- 6) Finally remember outputs are only as good as the inputs. Validate, monitor, check and review the changes made and adjust or redefine accordingly until everything functions seamlessly.

There are multiple suppliers of MES products and all to a lesser or greater extent carrying out the same or similar functions. They can vary greatly as to their complexity and many forms of user interfaces and connectivity. Nevertheless, the functions and principal of the chosen software solutions are to the same aim. The selection is down to evaluation and personal choices as to what fits the business best. (Flexware, 2022).

It is almost impossible to deny, that technology today is rapidly changing at a rate never seen before. There are significant gains that are available and achievable from the integration of Digital Systems within Manufacturing. Modern manufacturing today in almost every instance operates with digital information. Cost versus Revenue are what directly affects the viability and profitability of a business. Revenue mostly comes from sales, other avenues of revenue income or funding that could be sourced are typically in the forms of grants and loans. The success of any business needs sales, the level of which can be secured is reliant on the perceived image of the business which stems from its ability to deliver quality reliable products to the market place.

It is hard to envisage a manufacturing plant operating without an MES but many still do. As a result, many struggle to operate effectively and efficiently. They are heavily reliant on the good will of people, compiling and collating data manually. Staff are often over pressured and stressed, mistakes made and key data often overlook or lost.

i) **Benefits.**

The top five benefits to the business that can be accomplished by an MES listed below have been identified by SAP Insights are;

Top 5 Benefits of MES

Manufacturing execution systems track a huge amount of data, producing real-time insights that can boost production efficiency and save costs. Other benefits of an MES include:

1. **Improved quality control:** As quality control information is transmitted in real time, companies with an MES can immediately halt production as soon as issues are identified. This reduces waste, scrap, overages, and re-work.
2. **Increased uptime:** An MES generates realistic production schedules by balancing personnel, material, and equipment resources. It integrates scheduling and maintenance to maximize product flow and asset utilization – increasing uptime and improving overall equipment effectiveness (OEE).
3. **Reduced inventory:** A manufacturing execution system updates inventory records with new production, scrap, and non-conforming material so that your purchasing, shipping, and scheduling departments know exactly what material is on hand at all times. This reduces just-in-case inventory and work-in-progress (WIP) inventory – saving money on manufacturing, transportation, storage, and inventory monitoring.
4. **Paperless shop floor:** Eliminating paperwork means there is less chance for human error. It also means that the data recorded from the shop floor is immediately available to decision-makers across all integrated systems, to inform real-time decision-making.
5. **Improved product tracking and genealogy:** An MES follows the entire production cycle from beginning to end, grouping final parts or batches with the corresponding manufacturing data. This data allows for improved regulatory compliance for manufacturers that must conform to government or industry regulations.

(SAP, n.d.)

ii) **Equipment and Assets.**

In many instances new plant and equipment have inbuilt functionality and/or industrial computers connecting to an MES and sometimes passes more in-depth process information data providing far greater flexibility and control of the production process.

It is not necessary to spend hundreds of thousands of capital investment on new equipment. There is a vast array of IIoT bolt on devices that are readily available in the market place can be added to legacy machines and equipment that can provide usable information to an MES. In some cases the data maybe basic information such as, ON or OFF, STOPPED or MOVING, nevertheless, the information is relevant

and is sufficient data to interact with the MES enabling improvements across many aspects of the production flow process and provide greater control from vital usable status data. For example, let us consider a lights-out operations, an automated continuous flow line could be instantly stopped if required by a sensor monitoring movement should a failure occur in a piece of equipment. Thus preventing severe damage and expensive repairs to other associated equipment feeding up to this point. Being part of an MES could be just the beginning of an automated sequence of subsequent actions. These could be an automated sending of an email or text message such as notifying the production manager and maintenance staff of the problem allowing for, immediate corrective action to be carried out enabling recommencement of the production process as opposed to walking in on stopped production several hours later in the morning to find the anticipated planned work incomplete.

iii) **Productivity.**

This new innovative smart technology provides many gains to the functionality of a business. Results through key performance indicators (KPI's) such as quality, cost delivery and efficiency can demonstrate improved performance that is measurable in many ways. The likelihood is to see increased quality of products and more right first time items produced. Reductions in manufacturing times and less waste of materials, labour and time and reliability of processes and equipment. The interaction between, machines, equipment and computers, there is a seamless inter-change of information allows for immediate intervention or change to be applied either automated or through manual intervention providing further improvements. An MES provides a more efficient, effective, controlled production flow process, as indicated in (i) above.

iv) **People.**

The streamlining of processes and documentation through use of an MES application generates a positive effect for staff. Waste elimination is fully achievable through the removal of the requirement for continual manual reporting and intervention. This in turn allows staff get the job done right first time, with reduced pressure and a sense of positive achievement thereby becoming more efficient and productive, providing a feeling of self-worth through positive contribution.

SAFRAN Industry 4.0 Project

The collaborative work taking place at SAFRAN Seats GB MU (Manufacturing Unit) between, design, engineering, operations, quality, IT, strategic purchase, aftermarket and others have during the compilation of this paper have identified where the potential biggest gains can be made through the next stage of Industry 4.0 Advanced Manufacturing in its quest to gain prominence within the upper market levels of aircraft seating. The project to investigate and identify capital investment of new potential technology and machinery was originally scheduled commence in 2023 as part of a five-year medium-term potential investment investigation.

Due to the demonstrated business performance of the Manufacturing Unit, commitment of staff to excel and meet difficult challenges faced because of the impacts of covid19 and post recovery. The drive, enthusiasm, willingness to change did not go un-noticed. The executive committee requested an overview from the operations management team of the intended strategy for 2023 in MU. A presentation put to the committee with what was being considered as a suggested route forward outlining the top-level productivity and financial benefits.

It was so well received that a pull forward decision resulted and the program was escalated to an action as opposed to an investigation at the beginning of July 2022, with the added challenge of having everything in place and the first 5 axis machine fully productive with all other required systems to maximize opportunity be fully functional before the end of the final quarter of 2022 with the capacity to be interlinked and ready for expansion through follow up subsequent phases.

Everything detailed in this paper has played an instrumental part in the decision-making process and has steered and allowed the right choices for the business to be made.

Conclusion.

Invest and Deploy a Manufacturing Execution System or Not?

Recently the pre-commitment phase came to completion, after going through the processes whereby consideration and investigation took place to identify viable suitable solutions in the marketplace. Several manufacturers of machine tools, control systems, measuring equipment, work holding, tool holder, cutters, software options and plant layouts were all vetted, investigated as part of the pathway to finding a robust solution to provide up to date technology and manufacturing capability as part of the first of several phases to take place in line with the business mid-term strategy plan and Industry 4.0. Below are the investment considerations.

Hardware

- 1) Machines identified are 5 Axis Mazaks, a VTC 800/20 and VC5-500 with smooth tool Artificial Intelligence (AI) technology.
- 2) Work holding with modular Single Minute Exchange of Die (SMED) technology (5th Axis).
- 3) Cutting tools, a range of solid carbide and tool holders with quick change carbide tips researched, identified and technically assessed. All of which are readily available from mainstream suppliers such as Emuge and Iscar.
- 4) Options for tool measuring (offline Nikken, online Renishaw).
- 5) Option for online component measuring (Renishaw).

Technology

- 6) Work measuring on the machine (Renishaw) for first article inspection (FAI).
- 7) Considered, offline (EdgeCAM) and online (Mazatrol) programming solutions.
- 8) Pre and Post programming, cutting speeds and tool path optimisation.
- 9) Digital twins of machines with SIMUL (EdgeCAM) and
- 10) Direct transfer of models and model data connectivity allowing import of files, either directly to the machine or offline programming solutions.

Aside from the hardware and technology listed above, due considerations given to and taken into account:

- a) Identification of age equipment needing removal to provide space
- b) Floor lay out to best optimize use of space.
- c) Potential disruption to production, short and mid-term demand.
- d) Training requirements, operating, setting, programming.
- e) Detailed cost analysis.
- f) Provisional timeline plan with top-level actions.

Finally, probably the most important main consideration identified component, being part of this journey and a prominent inclusion for this project, never previously deployed in the Cwmbran manufacturing unit was to identify and include a Management Execution System. It would provide many significant potential efficiency, optimisation and improvement benefits, especially with it being integrated with our other management system software linking with the new M3 (ERP) system.

The MES has not yet been finalised but likely to be Mazak iSmart Factory, using Smooth Monitor AX *Figure 4* and Smart Box (MT Connect Mazatrol), *Figure 5 (as previously illustrated)*, Smooth AI (Mazak). Linking to all other existing digital tools as well as the proposed new technology. It has been agreed that as future expansion project would be extremely likely to introduce further Mazak machines then the recommended solution would be an all inclusive Mazak technology, Safran working partnership with the manufacturing unit.

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