

A report on

Advanced Industry 4.0

ACPA 7000 Assignment 1

University of Wales Trinity Saint David
(MADE Project)



By

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Introduction

It is now common knowledge in manufacturing that we are experiencing a wave of new technologies that will completely redraw the techno- economic paradigm underpinning our economy and society. Technologies such as Robotics, AI, IT, Renewable energy, smart sensors and 3D printing are these days normalised and readily available for manufacturers. These technologies create the opportunity to create new production model inside the factory, between factories and between integrators. Three main changes capture the emerging manufacturing model.

- 1) Digital technologies are increasingly adopted throughout the production process, and inside factories, intelligent machines enhance uptime, productivity and the flexibility. Smart sensors, digitalisation and robots are altering manufacturing factories.
- 2) New technologies lend themselves to efficiently scaling down productions, opening up new opportunities for small producers which can tap into market niches for personalised, customised and innovative products. Digital communications and 3D printing technology, for instance, enable innovators and inventors to again become manufacturers, as was the case during the First Industrial Revolution, and to connect directly with markets. Closer interaction between innovators, manufacturers and customers translates into more distributed manufacturing, whereby customers source or commission the making of products locally.
- 3) Almost all new technologies can be deployed to enhance the environmental sustainability of production processes and consumption via energy saving, bio- based products and remanufacturing or reusing of components. Adoption of new

technologies will vary depending on individual company's capabilities and processes and buy in from directors and business owners may not be there from the outset.

Main content

To identify current manufacturing systems I will look at highlighting the main systems within my business or previous businesses I've worked in that are critical to business success.

There are 3 main criteria that I have found common in manufacturing that support the success of a business and I will evaluate what they are, who they impact, why we use them and how industry 4.0 can develop them in current manufacturing.

To identify the main 3 system I have thought about various departments from Maintenance, engineering, Quality, operations and supply chain, all of which have a wide range of scope to integrate industry 4.0 technologies.

System 1: Data (Connectivity and sensors)

System 2: Operation and Control systems

System 3: Communication- CMMS, Digitalisation

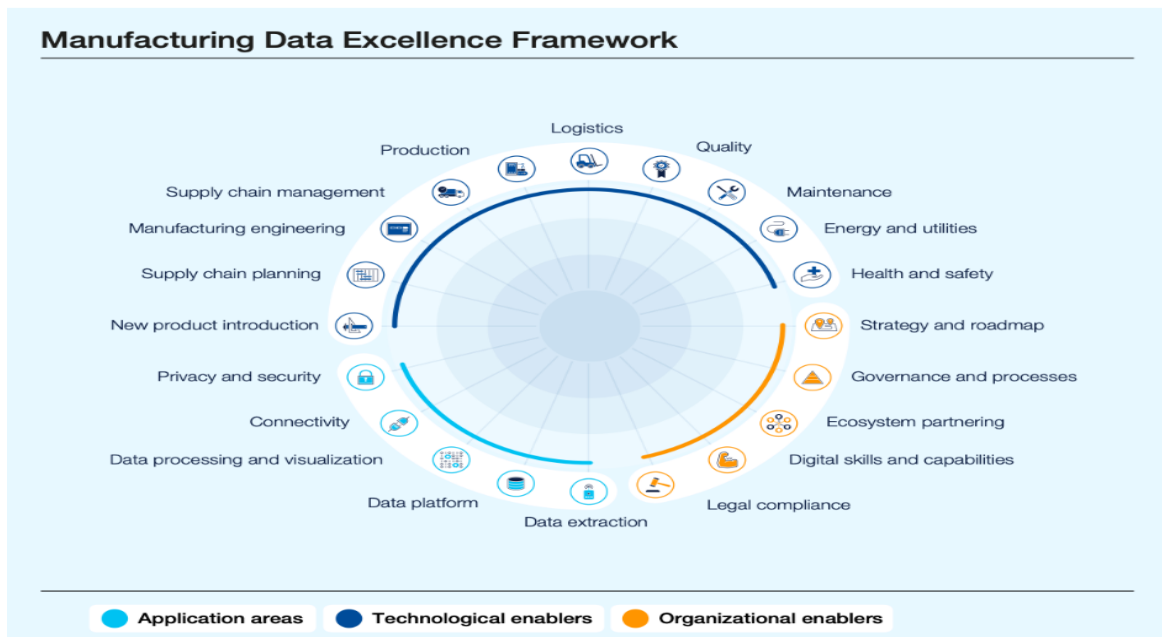
System 1

All manufacturing facilities require data to succeed. Data comes in various forms and in various depth. I've worked in business where data has been minimal and excessive with no wrong answers as long as it suits the business scope and needs. During the third revolution about 35 years ago, the concept of data collection for process control took a major leap forward. (SCHUETZ, 2017). With more digital systems coming on line data was available but not embraced by all for many years. Smaller companies and for sure family run companies it would take many years or decades to embrace data. My first exposure to manufacturing in the 90's was with a small to medium manufacturer that had just moved out of being a family run business. It was around the time where electronics and economics had become

digital. The internet was alive but not readily available to most and most certainly not used within the local manufacturing business. So what was a data manufacturing system and what did it become?

Firstly as an engineering apprentice data seemed to be a highly guarded secret that never flowed from the office to the shop floor albeit a lot of data was collected at the shop floor and made its way to the offices where decisions seemed to be made. Most operations data was paper based and archived in filing cabinets. Shift reports, raw material ledgers, batch history are examples of working documents that would see multiples of shift paperwork being produced to control and communicate. If any information required sharing on the back of these reports, they would not be sent by email but by fax or even pigeon hole inboxes. That quickly changed with PC's becoming more affordable along with digital systems and storage making a lot more sense. There was still a cultural change in many businesses though and changing culture can take many years to break. In manufacturing, data helps create end-to-end connected value chains. You need this to be more sustainable and agile, to improve productivity and drive an innovative customer journey (forum, 2022).

For many years I worked within companies where this statement didn't make economical or business sense. Too many times I heard "if its not broken then don't fix it" but as new people joined the business a cultural change was beginning and the idea of digitalising data was becoming the norm. Paper still had its place but a digital frame work was being built with all department starting to use databases and PC's for logs, emails and spreadsheets for speed of sharing data. Go No Go gauges and checks carried out by weighing and measuring systems started to become the norm with data automatically stored at PC's on networked systems. For departments such as Logistics, operations and Quality (QC) data was part of the daily job but maintenance was being left behind.



<https://www.weforum.org/agenda/2022/09/manufacturing-data-advanced-analytics/>

The aforementioned was until recently deemed as advanced by myself and its only since moving to a corporate company has data been used more widely albeit still very much manually collected, collated and communicated. So what does data collection look like at my current company. I will elaborate on this using the manufacturing shop floor as the example.

Currently all data is inputted at line side Client PC's into data bases or dedicated software packages that upload data to Automatically create graphs or trends that can be used to assess KPI's and performance. Depending on the area of work QC checks such as checking parts for compliance with tool and gauges can mean either the tools are connected to the line side PC with digital outputs enabled or transmitted digitally through Wi-Fi enabled devices. These sort of checks are a base for industry 4.0 but other aspect of machine data is not collected digitally due to a lack of infrastructure with the machines. Sticking with the QC department who are responsible for ensuring that as many parts as possible are kept within

specification, the more amount of data captured automatically the less chance of error. QC checks are critical in most manufacturing but even more so in the food industry. If I think back to QC checks I've worked with that automatically collected data, albeit in isolated machines that brought on beacons/ alarms or sent emails digitally but still not entirely on a networked system. Mettler Toledo was a supplier I used in food and now also in plastic manufacturing and supplied equipment such as metal detection, check weighing, visual inspections and x-ray machines (Toledo, n.d.). All these equipment types collect real time data that is used to populate databases as proof of product spec and conformity. The benefits of this data that doesn't require human input is:

- Data accuracy
- Optimised efficiency- failures are found quickly resulting in less scrap products
- Less customer complaints- Product quality KPI's can be very high.
- Cost reduction with less waste and less over runs, Staffing could also come under this category with automatic checks taking of the physical but there is also an economic factor to take into account with this.
- High quality products- The more QC check and data provided equates to higher grade 1 products.
- Better utilisation of staff- with staff having to complete less Physical checks and less data input there time can be best spent elsewhere in the process.
- More accurate production data tracking of product counts and types.

Although the systems used over the last few years have proven very successful the digital world continues to move quickly and open new avenues for data collection. Data collected is currently deemed to be very accurate but we as a company are aware that a lot of data

collect is still reliant on people and over the last few years we have been preparing our people and infrastructure for the future. Better collection sources for data is the aim with the two main focus areas being the internet of things (IOT) and supervisory control and data acquisition (SCADA).

(IOT)

(IOT) has arrived as one of the biggest changes to disrupt the digital world and in a much bigger way than what the internet did a few decades ago or evolution of computers did half a century before. It is driven by the need not just for manufacturers but also individuals to be able to follow and communicate with objects by combining the physical and digital world. (Sudrip Misra, 2021) IT and computing power has changed the world we live in over the last few decades but both businesses and individuals at home have not embraced technological change perhaps as quick as they should have. Even down to laser printers using smart sensors and algorithms to pre order new toner before things run empty allowing less stock to be held in storage is still in its early infancy in some business's . A lot of new Machine systems, programs and processors use individual IP addresses, interfaces or Wi-Fi and Bluetooth connections allowing access from the outside world or links into the digital world. With these type of connection it allows big data collection and analytics to be a whole lot easier.



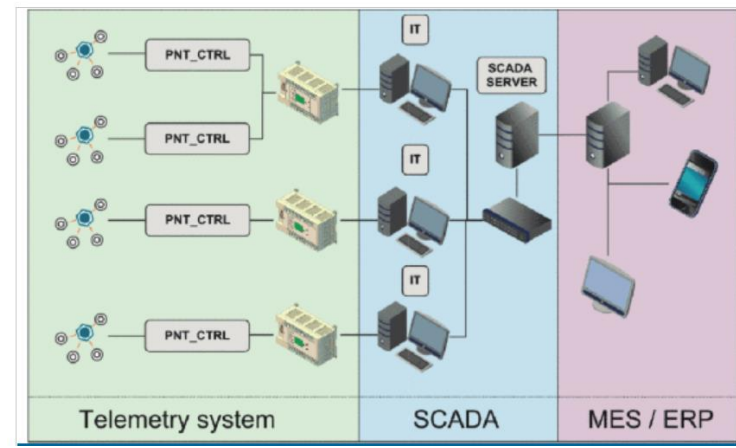
At home we can save our data on cloud based systems or dial into smart CCTV and door bells using Wi-Fi or static addresses. Energy data is readily available to us in the form of smart meters. The same or even improved technologies are available for the work place.

SCADA

Although I work for a corporate company our plant would be classed on the smaller side of the SME so a SCADA system always seemed a long way off and due to the roadblock of cost and engineering skill set. On the introduction of our internal Berry industry 4.0 initiative a key benchmark was digitalisation. No longer were we able to think that making our machines faster and more reliable were enough but had to start thinking about data. The corporate world requires us to share live data and almost instantly be able to provide production output to our stakeholders and shareholders. At the Hanover Fair 2011 for the first time a synonym for such a new industrial revolution was mentioned, “Industry 4.0”. The focus of Industry 4.0 is to combine production, information technology and the internet. (Rauch, n.d.).

The fourth industrial revolution should extend to the whole production and supply chain of components and not only, as in past revolutions, to the mechanical manufacturing process of products and the associated process organization. The development of Industry 4.0 should provide a contribution to tackle global challenges, like sustainability, resource and energy efficiency and strengthen competitiveness. This was the aim of our SCADA implementation with the basic operation of SCADA is to gather real-time information or data and monitor equipment and processes in the critical framework, providing the connection among servers located at the Gemba (Usman, 2023). Production data this is live and displayed on overhead displays for our operators to see ensuring cycle rates are hit and

batch runs are accurately managed. All of a sudden SCADA was becoming available to a SME like us with justification another spend to install and upskill of engineers to manage the platform. (Carmona, et al,ND).



Selecting architecture and designing a SCADA system is described in an article by the institute of electrical and electronic engineers as having three levels (Carmona, et al,ND)

- 1) A telemetric system in charge of the field devices collection,
- 2) The SCADA system
- 3) A layer of intercommunication of data so the systems of the upper levels (MES, MRP, ERP) can have access.

Within the report the telemetry system's defined as a having a main function of remote measurement that send data to the main interface. Although I agree with the statement this is the section that was vitally important for us and somewhat unclear due to the vast openness of its nature. Basically all primary movements and measurements fall under the

telemetry system interface and data for this can be source from everywhere. We pick up data from sensors, scanners PLC,s and various other process controllers. These are not necessarily the main function of remote measurement but could be a secondary or an additional function.

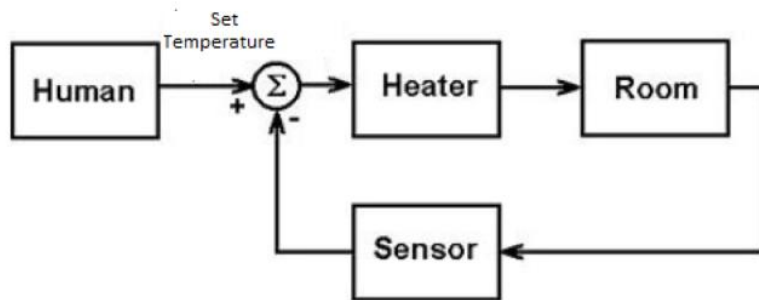
The business case to invest in advanced data collection is nowadays not a difficult sell, manual shop floor data collection won't any business to a level to compete in modern manufacturing and certainly not allow corporate companies to survive. Shop floor data can't be collected, analysed and shared between plants hundreds of miles away using manual collection of data. A system that can automatically collect, contextualise, and share manufacturing information so that your employees can focus on making decisions is a far better scenario and now a very common one. Most data is saved and shared on the cloud and can be accessed at the flick of a finger. Real time data allows employees and directors alike to see plant performance from the comfort of their home office or directly at the Gemba.

System 2- Operation and Control systems

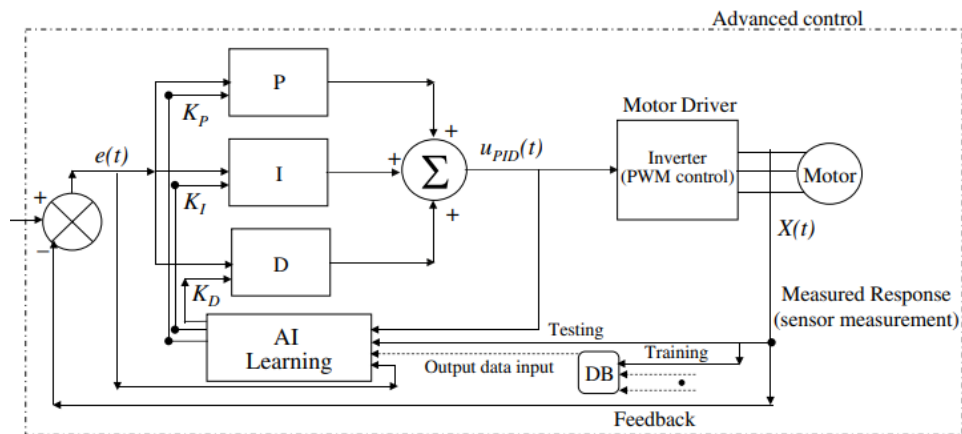
Control

A lot of systems in manufacturing are linked to each other and in basic terms control systems can stand alone or become part of larger SCADA and IOT systems. It's not uncommon to find a mixture of basic and advanced control systems within manufacturing. Industrial automation uses control systems to handle industrial processes and machinery and can range from very basic systems such as thermostats that control heating to large process automation.

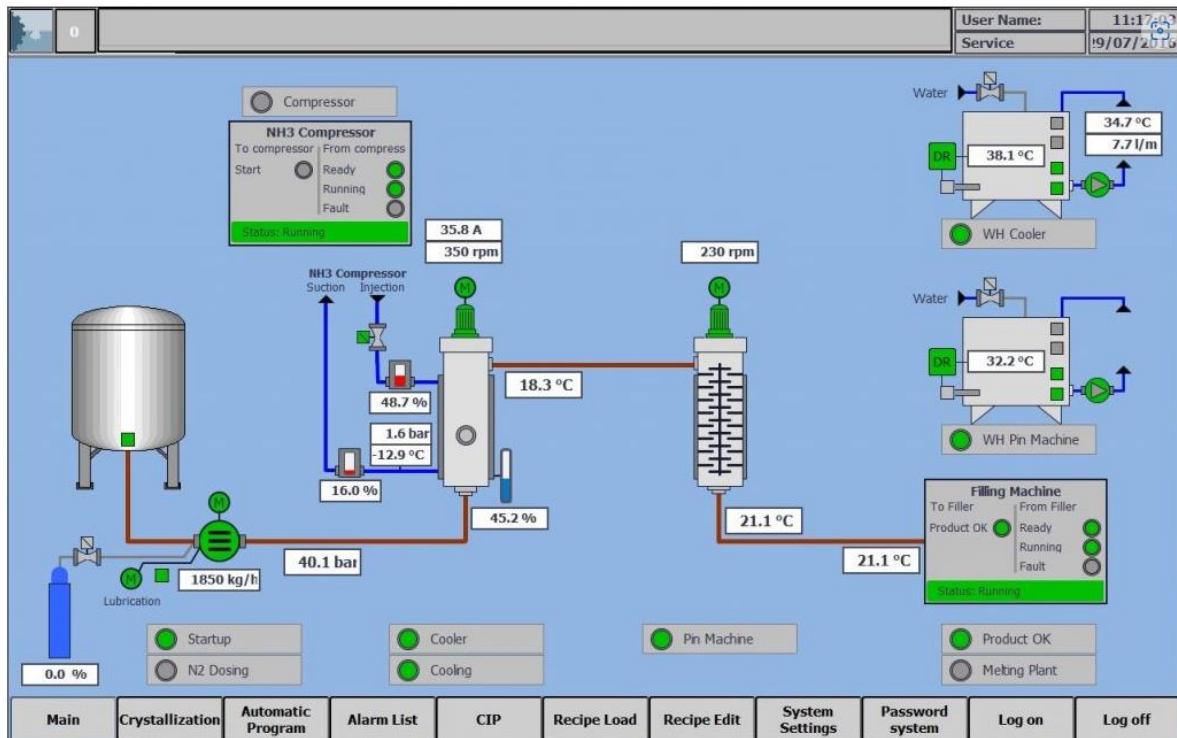
At an entry level discrete control systems with closed loop single control are used and are still common in manufacturing. Within extrusion machines closed loop PID controllers are used to bring on heaters and fans when temperatures are reached switching on solid state relays providing power to heaters. In its basic sense a light sensor to bring the lights on at a certain time or the thermostat of a central heating shows an entry level control system. The human element will act as the system programme where a temperature will be set, followed by the boiler coming on and heat becoming emitted through the radiator. The thermostatic sensor will then detect the temperature and knock the boiler off when the set point is hit. This process then sets on a continuous loop where by when the temperature drops the boiler will come back on etc. There are most basic control systems where mechanical thermostats incorporate the temperature sensor with a static set point control button but these are rarely seen nowadays.



The concept is simple with even more elaborate PID control systems using the basic principles and in single circuits this is more than acceptable but when more control or finer control is required distributed control will be found most commonly in the form of PLC's. Distributed control (DCS) tend to be digital and is generally used in plants or processes where control functions are distributed throughout the system. Common control such as PLS's provide the option for custom-designed processors as controllers with individual types of communication connections. These connection can then be in the form of inputs and output that could be analogue, current loop or even bus type signals. These systems have been around for many years and still play a big part in manufacturing control systems and are also the foundation of more advanced systems. A modern example would be an advanced control system of robotic motors providing the feedback loop system, where the PID controller and the AI Learning module are combined supporting together the error estimation for the best setting of the control variable (Massaro, 2021). As you can see below the basic PID system exists with a common feedback loop but modern systems allows AI learning and increased output data to be added to the feedback loop.



Although distributed control provides modern and fine systems the natural path from there is to SCADA control systems for increases levels of automation and data acquisition. SCADA systems are highly distributed systems used to control dispersed assets that are often a long way away from the source of control. They are used through manufacturing and in lots of distributed systems such as water distribution, oil and gas pipelines and electrical power grids. SCADA monitoring performs centralised monitoring and control for fields over a long distance along with providing big data collect. (Hayden, 2015). The below example shows one page of a relatively small SCADA system for a filling machine at a bottling plant. Although it looks different to a basic system controllers are still using set points and feedback from sensors to operate the system and also store and collect the data from the system. For example the compressor temperatures and pressure will not only be set on the SCADA but stored and trended within the system. Generally by clicking on the sensor the trends tab historical and live data for that part of the system can be seen.



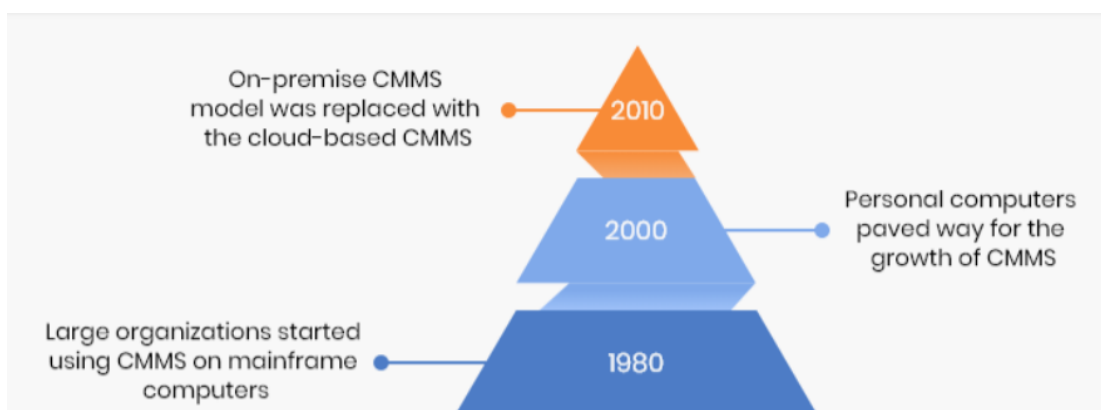
SCADA systems are typically implemented to control system architectures by graphical user interfaces (GUIs), and behaving as a supervisor of peripheral devices such as PLC, and proportional integral derivative (PID) controllers interfacing process plant and production machinery. Typically, SCADA adopts visualisation tools and synoptic graphics for real-time data display (Hayden, 2015). Without SCADA software, it is extremely difficult to collect enough data for consistently well-informed decisions. In addition, most modern SCADA design applications have rapid application development capabilities that allow users to design applications relatively easily, even if they do not have extensive knowledge of software development. The introduction of modern standards and practices of IoT, SQL and web-based applications into SCADA software, have greatly improved the efficiency, security, productivity, and reliability of SCADA systems. A great benefit of using SQL DBs with a SCADA system is that it simplifies integration into existing systems, permitting data to flow

in the information system. Historical data of a SCADA server can be also migrated into a not only SQL (NoSQL) big data system (Hayden, 2015).

As control system move from SCADA engineered control system and become incorporated into more IT based and cloud based control systems there will be economic and cultural challenges to a lot of manufacturers. With most systems now able to integrate and digitally talk to each other, systems are getting user friendly but two challenges we will see is a lack of skillset in engineers and security risks that need to be thought about when building control systems.

Communication- CMMS, Digitalisation

With more advanced control systems it's allowing operations to integrate with control systems especially with SCADA. Computerised maintenance management systems are designed to form part of a preventative maintenance strategy and have been around for many years. Early version of CMMS was very limited (basic work orders) and used by only very large organisations and government to manage maintenance operations (Lachance, 2021). From the late 1980s to the early 2000s, the technological advancement of the personal computer paved the way for the growth of CMMS software. The expanded ability to connect the PCs together with the local area networks widened the usage of CMMS capabilities. After the 1990s, expressly from 2000, there was a tremendous evolution of the internet and cloud to drive the maintenance process. Post year 2000 CMMS was more widely available to manufacturers with IT infrastructures getting better and the Internet becoming the norm but quite often these systems were not freely available to all. It is not unusual for CMMS to be secluded from other systems and working in isolation (Malhotra, 2018).



(Choudhary, n.d.)

The latest versions and adaptations of CMMS see packages not just include Maintenance scheduling but also incorporates safety, quality, productivity and real time tracking of

performance with the ability to collate big data. Much like as described in the QC data collect above production and maintenance data was historically paper based or at best by the use of basic spreadsheets. (Choudhary, n.d.). These methods were quite labour intensive and although raising work orders and maintenance planning was easy to carry out there was lots of limitations especially when it came to trending and tracking. Paper work would go missing or errors not picked up and creating a trend quite often involved duplication of what had already been produced. Communicating a change to production or maintenance plans left a lot of scope for error and production or maintenance manager were left to make changes to every step of the process. With these constraints, time, costs, resources, and staff allocations are done as needed, but this will not provide revenue to the company but sap people's time.

The role of the operations and maintenance team has changed from every perspective over the years with both being responsible for the development and success of the company. The maintenance team, supported by software like CMMS uses a proactive approach to increase efficiency, reducing downtime, inventory management, and team safety. This helps the managers to make sure the factory is ready for adversity and demands of the corporate world. Industry 4.0 combines all the original aspects of CMMS while also employing smart technology to intelligently connect everything. Machine-to-machine, people-to-machine, etc. The internet of things (or IoT) is a key part of this revolution, but there are numerous other "exponential technologies" (artificial intelligence/machine learning, additive manufacturing, augmented/virtual reality and much more). The goal is to enable autonomous decision-making processes, monitor assets and processes in real-time all connecting back to the business enterprise in real time. Enabling work orders, condition monitoring and QMS systems linking training documents and risk assessments all available

on a cloud based system is now almost standards platform for most systems (Zaptic, n.d.). CMMS along with SCADA created a great platform to develop visual management and part of a digitalised operation system. Digitalisation is transforming our society in several ways, bringing several new opportunities and challenges for firms operating in this dynamic setting. Within my manufacturing setting the digital influence has provided us with new ways of performing tasks and streamlining reports. Research around digitalisation focuses on the technological innovation however, digitalisation impacts not only digital capabilities but also business models, operational processes, and customer experiences. According to Orlikowski and Iacono (2000), such an impact is not merely restricted to the internal organisational structures, but also has consequences for the external interconnected environment of the organisation and are made up of four levels (Mattias Elg, 2020)

1. Process level – changes in how work tasks and activities are carried out by implementing new digital tools or digitalising previously manual activities.
2. Organisation level – new ways of providing existing offerings, as well as providing new offerings enabled by digitalisation
3. Business domain level – changing roles and value chains
4. Society level – reshaping types of work, competence, and infrastructure for digitalisation

Our digitalisation started with the automation of completed production lines using digital systems and smart sensors to control machines and collect data along with problem detection and SCADA systems. The SCADA system then allowed Automation to be developed further, enhanced communications through TV's and cloud based access and eventually a change to business models.

Impacts, applications and conclusion

Industry 4.0 (I4.0) represents a radical change in firms operations that is particularly challenging for small and medium sized enterprises (SMEs) due to the substantial need for capital and knowledge (Matt, 2021). The main reason SME's look to get on board with industry 4.0 is to digitalise, communicate between humans and machine, collect real time data with the end impact of improved production, accurate data and smarter tools allowing collaboration of everyone and everything in the manufacturing area. Consequently, I4.0 arises from its elementary technologies, which lay the foundation for the integration of intelligent machines, humans, physical objects, production lines, and processes to form a new kind of value chain across organizational boundaries, featuring intelligent, networked, and agile production (Alcácer and Cruz-Machado 2019).

While Industry 4.0 is clearly becoming a source of economic benefits for a share of firms in the economy, it also carries some risks (Cézanne, n.d.) Risks of different kinds that are regularly highlighted include, economic risks associated with high investments, social risks associated with job losses, technical and IT risks inherent in data security, legal and political risks of data ownership and data protection. Sustainable development in the Industry 4.0 context contributes to circular economic objectives by achieving social, economic, and environmental benefits (Kahn, 2021). Job losses will play a big part in Industry 4.0 and as business apply for Capital or Grants to install industry 4.0 technology they have to be mindful of labour. Although there will be job losses with-in unskilled labour there will be new jobs created for the skilled workforce that are required to install and upkeep new platforms. This may not be a linear swap of job sectors but it's something all businesses should take into account. There are also concerns regarding the lack of skilled labour and training available to upskill the workforce and the impact Covid had on developing skills.

Half of the workforce will need to reskill in the next five years, as the double-disruption of the economic impacts of the COVID-19 pandemic and increasing automation that transforms jobs (Whiting, 2020).

One thing I've not spoken about in detail is the environmental need of industry 4.0 and energy monitoring. With so much focus on rising costs, smarter and more digital energy monitoring will play a big part in most sectors most certainly within plastic manufacturing where after Raw materials, energy is the biggest cost. Another interesting application is cyber security which as we become more digital is going to play a big part into our own Industry 4.0 journey. As a company we are perhaps behind lots of others on our I4.0 journey but each and every topic I have spoken about are tools we are working with in our Business models and are adding real time value to sustaining business and business growth.

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