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DIGITISATION IN THE CHEMICAL INDUSTRY

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DIGITISATION – THE WAY FORWARD

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At the Chemical Industries Association we have been studying the impact and potential of digitisation for some time. This report sets out our latest thinking. According to a 2018 Accenture report *Industry X.0: Unlocking the Power of Digital in Plant Operations* the adoption of digitisation and big data will generate a step-change in productivity and could precipitate the creation of new business models. Innovations in this area are being taken up by industry, with 80% of 360 chemical companies reporting an increase in investment in digital technologies for plants, in particular on plant management and product quality. In order to maintain and improve global competitiveness, the UK industry should play a leading role in this quiet revolution. Digitisation and Big Data is one of four themes identified by the Chemistry Council – the joint Government/industry sector council for the UK chemical industry – which should be addressed to accelerate the commercialisation of science in the UK.

This report briefly reviews the status of digitisation within the UK chemicals sector, makes suggestions on the way forward, as well as the role Government can play in helping adoption. Digital techniques offer potential to improve all areas of business, from predictive maintenance to product traceability, and production efficiency to reduced R&D lead times – there is a tool or technique for everyone. However, there is understandable reluctance from some businesses to take the leap forward. These concerns include cyber security, lack of case studies, cost of technology and the lack of skills to fully understand and implement the technologies. This report touches on all these.

Although the skillset to fully identify and adopt these digital technologies may not be available in every company yet, the expertise is certainly out there. We are grateful to three of our Associate Members who have expertise in this area – **ABB**, **Elutions** and **Siemens** – in helping pull this report together and who all contributed to our first Digitisation conference in 2019, where successes and concerns were openly discussed.

INTRODUCTION

The UK chemical and pharmaceutical industries have a strong record as manufacturing's number one export earner and a provider of essential inputs to UK value chains, including products and technologies which are key enablers of climate change. As such, a growing and competitive sector is essential in enabling other sectors to thrive and help the UK to grow sustainably. As a consequence, the sector has a strong contribution to make to both rebalancing and 'greening' the economy. The chemical and pharmaceutical sector adds over £18 billion of value to the economy on sales of over £50 billion, is responsible for around 500,000 direct and indirect jobs and pays its direct workers on average 34% more than the average manufacturing worker.

We are trade intensive and, with 70% of operations headquartered overseas, we compete with global production locations for mobile investment capital. In 2019 the industry spent £5.9 billion on business investment including investments in buildings, vehicles and machinery, whilst a further £5.4 billion was spent on research and development, equivalent to 21.4% of total business spend.

The implementation of digital techniques, Big Data and Artificial Intelligence (AI) in manufacturing processes, logistics, supply chain management and R&D is increasingly becoming critical in strategies aimed at improving productivity, competitiveness and profitability across many sectors. However, in some sectors uptake and implementation has been slow, with challenges such as cyber security, lack of case studies, new unproven technologies, cost and risk aversion being cited as reasons for lack of action.

There are several digital techniques, as shown below. In this document, 'Digitisation' is the generic term used to cover these.

- Artificial Intelligence
- Virtual/Augmented Reality
- Digital Twin
- Cyber-Physical Systems
- Big Data/Smart Algorithms
- Internet of Things
- Advanced Robotics & Cobotics
- Cloud Technology
- 3D Printing/Additive Manufacturing
- Cyber-Security

The Covid-19 pandemic has brought renewed interest from organisations looking to, for example, work more productively from home, find alternatives to work that can't be done with social distancing and maximise supply chain efficiencies. This document outlines the status of digitisation efforts within the UK chemicals sector as well as the opportunities and challenges in adoption of digital technologies bolstered by case studies and examples. Finally, it offers strategic suggestions for increasing the uptake of digital technologies within the sector to improve competitiveness as the UK adapts to both life outside the EU and the impacts of Covid-19.

INDUSTRIAL DIGITISATION IN THE UK

At its simplest, industrial digitisation is the application of digital tools and technologies to the value chains of businesses that make things or are otherwise operationally asset intensive. These technologies enable the physical and digital worlds to be merged and can bring significant enhancements to performance and productivity.

The UK Government commissioned an independent review, led by the then Siemens CEO and Chair of Made Smarter, Juergen Maier, which reported in 2017 on how UK manufacturing industries can prosper through digital tools and innovation. This Made Smarter Review involved over 200 organisations from manufacturing, academia, trade bodies and technology companies. It identified a potential prize of £455 billion for UK manufacturing over 10 years, with the creation of 175,000 jobs, a productivity increase of 25% by 2025 and a carbon emissions reduction of 25%.

The report also identified eight barriers which could prevent this potential prize from becoming reality:

- Cyber security threat
- Skills
- Lack of Industry 4.0 understanding
- Limited access to innovation
- Poor infrastructure
- Perceived cost
- Limited empirical evidence
- Existing legacy

COMPUTER SECURITY, CYBER SECURITY OR INFORMATION TECHNOLOGY SECURITY IS THE PROTECTION OF COMPUTER SYSTEMS AND NETWORKS FROM THE THEFT OF OR DAMAGE TO THEIR HARDWARE, SOFTWARE OR ELECTRONIC DATA, AS WELL AS FROM THE DISRUPTION OR MISDIRECTION OF THE SERVICES THEY PROVIDE.

Several key recommendations came out of the report to help overcome these barriers:

- To build a national digital ecosystem that will be more visible and effective, accelerating the innovation and diffusion of industrial digital technologies. This included a National Adoption Programme piloted in the Northwest.
- The upskilling of 1 million industrial workers to enable digital technologies to be adopted and exploited through a single Industrial Digitalisation Skills Strategy
- Investment in large scale demonstrators to prove the application of digital solution at scale in production. £147 million (plus industry match) was approved within the Industrial Challenge strategy Fund Wave 3 to support digital manufacturing accelerators.
- The establishment of a national body, the Made Smarter UK (MSUK) Commission, responsible for developing the UK's own Industry 4.0 domestic and global strategy and brand.

By the summer of 2020 almost 1000 companies had received some support from the North West Made Smarter pilot, with over 100 companies receiving matched support for specific projects forecast to deliver an additional £100 million in gross value added.

Industrial digital technology has the potential to create benefits across a manufacturing organisation's whole work processes, from sourcing materials to distributing product, ultimately aiding a circular economy. Focusing on the manufacturing process itself, some of the key benefits that help achieve this productivity and competitiveness prize include:

- Real time visibility of processes/supply chains
- Recording of all process conditions and parameters
- Shortened changeover
- Improved quality control through data analysis and automation
- Eliminating ergonomically disadvantageous tasks
- Faster machine fault diagnosis
- Integration of data from R&D and manufacturing
- Improved maintenance efficiency
- Increased productivity
- Increased profitability, e.g. reduced energy and waste
- Faster innovation

DIGITISATION AND CYBER SECURITY

Cyber Security concerns can be a barrier for many chemical manufacturers driving a digital strategy. Unfortunately, it is a reality that on industrial control systems for example, attack surfaces are growing. This is due to demands on remote access, human error, distributed denial-of-service attacks and malware.

When we also consider the age and lifecycle of many industrial control systems in the field, they cannot be updated due to IT and OT (Operational Technologies) system obsolescence, and therefore risk attack if connected to the outside world. With the investment cycle for operational technologies being 20 years or more, the real issue is that legacy systems always need to be considered – either replacing them or integrating them. The latter being the most common.

Covid-19 has accelerated the need for home working and remote access. This puts even more focus on industrial cyber security as an integral part of digitisation of the industry.

Concerns over cyber attacks have grown gradually since the widespread use of the internet in the late 90s, with actual security threats increasing and becoming more sophisticated in the last ten years with cloud computing and the internet of things (IoT). From a chemical company perspective there is the particular concern over the threat to control systems. These threats may take the form of:

- Phishing attacks
- Infiltration of malware through removable media and hardware
- Malware infection from the inter- or intranet via remote access
- On-site sabotage
- Control components connected to the internet
- Compromising of Cloud components
- DOS attacks
- Smartphones in the production environment

Specialist advice is required to make sure defence systems are as robust as possible, and, as a minimum, hardware and software should be up to date and the latest standards and frameworks adhered to. Organisations are advised to adhere to National Cyber Security Centre Guidelines.

CURRENT STATUS OF DIGITISATION IN THE CHEMICALS SECTOR

Several companies, including Deloitte, McKinsey and Siemens as well as Suschem, have issued reports on digitisation of the sector in recent years and all have highlighted the overwhelmingly positive potential of making better use of Big Data and AI.

Manufacturing operations present one of the biggest and most readily accessible areas of opportunity for embracing digital. The amount of data generated by chemical plants is huge, but most of it does not get analysed. Those companies that routinely use advanced analytics and act on the findings have seen significant benefits in terms of improved yields, shorter batch times, lower energy consumption, reduced downtime and maintenance etc. For many companies, addressing the 'low hanging fruit' by implementing these measures are potentially easy wins that can be achieved using existing IT and process control systems. Companies that expand beyond this data collection, investing more in digital, stand to capture further gains. Most new equipment is now WIFI enabled and equipped with sensors making collection and interpretation of data much easier. These additions add relatively little to the cost of equipment and can often be effectively added to older equipment. Many companies are installing this type of equipment in a staged way to 'trial' the improvements that can be made.

Predictive maintenance is often seen as one of the most visible benefits of digitisation across the whole of manufacturing industry. Using big data to analyse outputs such as vibration and lubrication levels, energy consumption, lubricant analysis and even thermal imaging may greatly reduce costs and improve quality versus standard maintenance procedures. Implementing predictive maintenance measures even has the potential to help avoid disruptive and costly unplanned events.

Advanced analytics and computational chemistry have been increasingly used in R&D laboratories for a number of years, especially in the pharmaceutical sector, where large numbers of screening experiments are typically carried out. Computational chemistry is a powerful tool to test theories regarding chemical transformations and new material properties at a molecular level. These virtual experiments do not require chemicals or equipment and can analyse thousands of parameter variations very quickly. Similarly, experimental data can be quickly used to suggest optimal synthesis routes for new molecules, greatly reducing process development costs.

Use of advanced analytics across the supply chain can make forecasting more accurate, distribution more efficient and product tracing readily achieved, leading to improvements across the sales planning and distribution processes. It may also lead to better production scheduling, and shorter lead times.

Digitisation also has a lot of benefits when it comes to designing new plants. With a plant having a typical lifespan of over 30 years it is worth employing the latest design tools to ensure the plant is optimal. One aspect of this is the Digital Twin in which a virtual plant is designed to look at both the process and operability

BIG DATA IS A FIELD THAT TREATS WAYS TO ANALYSE, SYSTEMATICALLY EXTRACT INFORMATION FROM, OR OTHERWISE DEAL WITH DATA SETS THAT ARE TOO LARGE OR COMPLEX TO BE DEALT WITH BY TRADITIONAL DATA-PROCESSING APPLICATION SOFTWARE.

of the design, to the extent of virtual people operating and maintaining the plant – streamlining the operability part of the Hazop process.

The use of digital techniques is often outside the scope of expertise for many in the industry and a cultural shift is required towards the value of analysts and digital experts, given the very substantial impact they can make on a chemical company's operating costs and competitive positioning. To this end, employees with a wide range of digital skills are increasingly being seen as an essential requirement for most chemical companies.

According to the Suschem report, of all the digitisation techniques AI offers the most potential to achieve disruptive transformations and will have a huge impact on value chains. AI-technologies have enormous potential to be applied within early product and process development stages to speed-up innovation, allowing a more efficient 'idea-to-market' process. AI can make industrial processes safer and cleaner and help invent new molecules for specific customer needs, including increased circularity of materials.

The Chemistry Council has recognised the importance of this area with Big Data and Digitisation being one of the four innovation themes identified. In particular, three key areas were highlighted:

- Digitisation of Supply Chains

  Incorporating digital technology throughout the supply chain would allow industry to better manage products, improve product traceability and provide efficient cash-flow management. Government support was identified as being required for collaborative research projects to develop technologies, such as molecular tagging, and a prototype digitised supply chain.

- New Process Technologies

  The sector has had a long record in developing and commercialising new processes and is constantly seeking innovation in process design. The adoption of new process technologies, such as continuous flow technology, will provide a step-change in capital cost, materials management and throughput, whilst new process technologies such as 3D printing creates the opportunity to establish new business models such as personalised products and localised manufacture. The market for polymers and chemicals used in additive manufacturing (3D printing) is growing at 30% a year and is set to rise from $0.7 billion in 2015 to $2.5 billion in 2020. Government support in the form of scoping studies, R&D funding and assets for digital design software was identified.

- Big Data in Design

  Big Data is already used within the pharmaceutical industry for molecular design. Its application could be an important underpin to accelerating innovation in other sectors, in particular where complex design is required. Government support to develop a prototype materials and formulation database, to be used for materials design in the first instance, was identified.

UK CHEMICAL INDUSTRY SURVEY

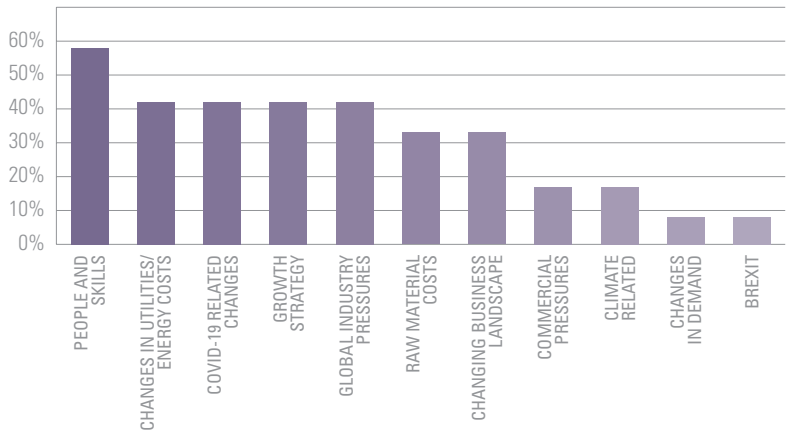
UK CHEMICAL INDUSTRY SURVEY

In partnership with Elutions, the Chemical Industries Association recently conducted a survey amongst its members to better understand the current status of digitisation in the sector, the main issues digital technologies could help resolve and the future journey to digitisation.

Asset downtime and plant failure was by far the major challenge seen by sites, with 100% of participants citing this challenge, followed by labour constraints and process planning.

As illustrated below, people and skills were a key area of operational challenge that members expressed were driving digitisation initiatives, followed closely by changes in utilities and energy costs, Covid-19 impacts, growth strategy and global industry pressures.

ADDRESSING OPERATIONAL CHALLENGES THROUGH DIGITISATION DRIVERS.



When it came to what technologies could drive operational improvements at site level, almost three quarters responded stating that advanced analytics was the most likely, followed by dashboards and reporting, closely followed by automation and AI or machine learning. In practice though, it is recognised that to achieve maximum benefit and transform operations, the challenges must be treated holistically through end-to-end application of Artificial Intelligence.

It was reported through the survey that the current experience with achieving benefits from digitisation projects is relatively poor, with only 8% being classed as successful, whilst 75% achieved only some or very limited benefit – something seen all too often with digital projects as many do not have clear objectives or success criteria prior to adoption.

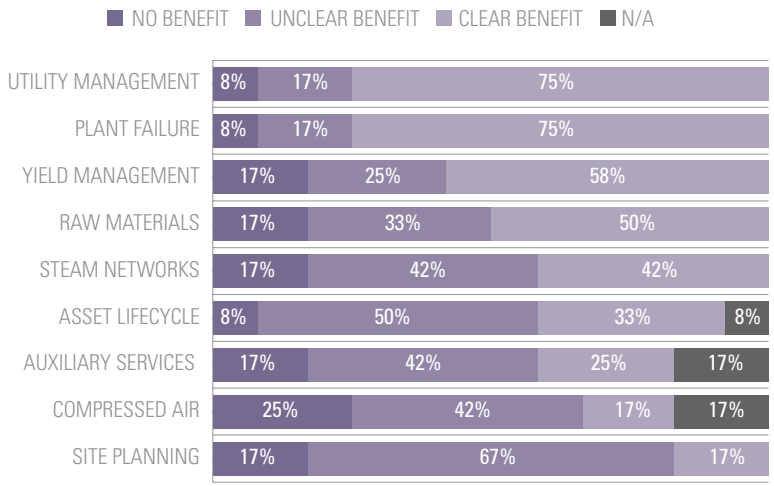
Currently, digitisation is not widely adopted with even the highest areas of adoption, process management, supply chain and maintenance being less than 20% established in organisations. However, 50% of respondents did indicate that they are currently deploying some digital technologies in maintenance and over 40% indicated some sort of adoption in process management.

Respondents shared that their current technical landscapes widely utilised sensors and alarms in the majority of operations. Systems control, data acquisition and storage were also widespread, but it was evident that the full potential was not being made of sensors or data. AI and machine learning was only embedded in 8% of operations.

Respondents indicated intentions to invest in digitisation projects in the next year over a range of areas, with the area of the boxes in the diagram below being proportionate to responses. It is customary for maintenance, particularly predictive maintenance, to be amongst the early projects identified for companies starting their digitisation journey. All respondents stated that adoption of digitisation at the group level is in the limited or very early stages, with most work being initiated at site level with some group input.

WHERE ARE DIGITISATION INVESTMENTS BEING MADE WITHIN THE NEXT 12 MONTHS?

WHAT IS THE OPPORTUNITY FOR AI TO RESOLVE OPERATIONAL CHALLENGES?



Looking to the future, respondents recognised that AI had potential to make a significant impact across most business areas, especially utilities management and plant failure.

These results highlighted that many companies are at the start of their digitisation journey, with very few yet seeing the full benefits it has to offer. Deployment is largely in specific areas, taking more of a discreet approach, with a move towards implementation of predictive maintenance to reduce plant downtime being most widespread.

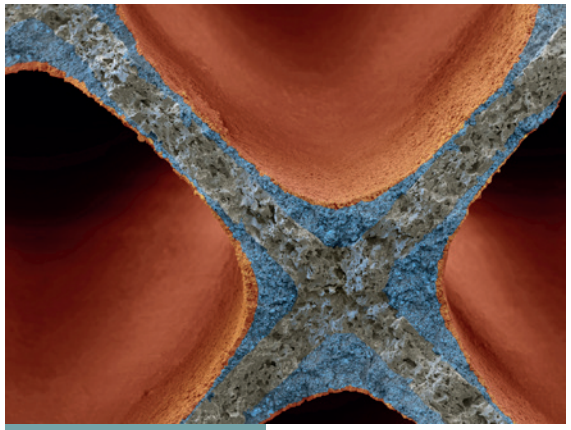
It is evident that if the sector is to realise the full benefits digitisation has to offer, it is critical that there be both more confidence in the benefits digitisation can provide and an improved understanding of where these benefits can best be obtained. For many, knowledge and understanding of digital techniques – especially how they can be applied holistically – to obtain transformative end-to-end benefits, is outside the scope of many of the traditional disciplines employed within the sector. To overcome this key barrier, we need better communication of successful case studies, demonstration facilities, reliance on experts and strategic partners and support for developing the skill base required to drive forward.

APPLICATIONS, EXAMPLES AND CASE STUDIES

Open Innovation Drug Discovery at Eli Lilly
R&D spending in the pharmaceutical industry exceeds $100 billion annually, and the average pre-tax cost of a new prescription drug is approximately $2.6 billion. As a result, pharmaceutical companies are looking for opportunities to improve R&D productivity.

Eli Lilly launched its Open Innovation Drug Discovery program, an online platform that encourages academic and corporate researchers to partner with them in the early-stage development of new drugs. Researchers are granted access to a wide-range of Lilly's internally developed R&D capabilities to further their research efforts. For example, researchers can access proprietary design tools for creating and modifying molecules and other compound structures. As these structures are developed, researchers can choose to submit them for screening, a process that uses in silico analysis to identify compounds with the potential for commercial viability. Other resources available to researchers include access to Lilly's library of proprietary compounds and remote experimentation in Lilly's automated synthesis laboratory. Researchers' data is stored confidentially on networks hosted by Lilly, and data shared with Lilly for testing is converted to 'encoded fingerprints' to protect confidentiality. If testing indicates a potential for commercialisation, Lilly has the first right to negotiate a licensing or collaboration agreement with the researcher to continue commercialisation efforts.

BASF and Citrine Informatics collaborate to use artificial intelligence to develop new catalyst technology
BASF and Citrine are collaborating to use artificial intelligence to accelerate the development of new environmental catalyst technologies. The key to success is matching product performance with speed-to-market. The companies are collaborating to accelerate innovation by implementing machine learning for research. The initial phase of the pilot project focuses on identifying new materials for capturing greenhouse gases. In the collaboration, BASF is providing experimental data to build proprietary AI models using the Citrine platform. By iteratively testing newly suggested materials from the models in the lab, BASF and Citrine aim to improve the models through sequential learning by retraining the algorithms with new data.



THREE-WAY CONVERSION CATALYST REDUCES EXHAUST GAS EMISSIONS.

Borealis Polymers Ltd – Dynamic real time optimisation increases ethylene plants profits
The real time optimisation project started in 2003, selecting Dynamic Real Time Optimisation Technology (DRTO) that took account of the natural inertia of the plant caused by process delays, has realised many benefits amounting to $12.5 million pa. Most of the benefits are due to a significant increase in production rates as a result of the project, leading to a payback time of a few weeks.

Borealis also uses data mining and modelling to develop dynamic target values for the energy consumption of the plant – accounting for factors such as the current conditions of the plant, outside temperatures, fouling of the systems, ageing of the catalysts, etc.

THE WAY FORWARD

The generation, collection, and storage of data have never been as readily available and cost effective as they are today, and computational speed power continues to grow as costs reduce. These have opened up new potential avenues for the chemical industry. Use of advanced analytics to extract information from the large amounts of unstructured data can be used to improve how plants are run and to make better-informed and speedier decisions across the full range of a chemical company's business processes. Even further, AI can be applied to existing operations in an end-to-end manner across the entire value chain to transform business operations.

In the global landscape, the chemical industry is an essential supplier to the vast majority of other industries, and so the ways in which these industries are being changed by digital is in turn translating to opportunities and challenges for chemical companies. The key issue for leaders is to understand more clearly where the impact of digital will benefit the industry and what it will imply for the future of their business.

There are however several key barriers preventing faster and more widespread adoption of digital technologies. In order to overcome these, we urge Government to implement the findings of the Made Smarter review and areas identified by the Chemistry Council, especially:

- Funding for collaborative research across the supply chain to develop technologies, such as molecular tagging, and a prototype digitised supply chain.
- Funding for R&D and scoping studies, in the design use and implementation of digital design software for the sector.
- Support to develop a prototype materials and formulation database, to be used for materials design in the first instance.
- Support for the up-skilling and re-skilling of people in digital solutions.
- Investment in sector relevant large-scale demonstrators to prove the application of digital solution at scale in chemical production.

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