SUMMER 2022 | ISSUE 13

IfM | REVIEW

FROM IDEA TO PATIENT

How the IfM is delivering new solutions in healthcare

UNIVERSITY OF CAMBRIDGE
Department of Engineering

IfM | MANAGEMENT TECHNOLOGY POLICY

IfM | REVIEW

INSTITUTE FOR MANUFACTURING (IfM)

The IfM is part of the University of Cambridge's Department of Engineering. We are a dynamic body of researchers, educators, practitioners, professionals and technical experts contributing to world-leading research and education. With a focus on manufacturing industries, the IfM creates, develops and deploys new insights into management, technology and policy.

IfM ENGAGE

IfM Engage is an embedded knowledge transfer company within the Institute for Manufacturing (IfM). We combine research excellence and industry expertise to conduct bespoke strategic consultancy, talent and leadership development and company membership programmes. Our profits are gifted to the University of Cambridge to fund future research.

COVER IMAGE

The IfM has been working on research in healthcare for over thirty years. Credit: Amy Reinecke/Institute for Manufacturing.

SUSTAINABILITY

This magazine was printed using a naturally grown toner on recycled paper, in a factory powered by 100% renewable energies, that produces zero waste to landfill, and is beyond carbon neutral in its impact on the environment.

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Editors: Jason Naselli and Elizabeth Tofaris

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WELCOME TO ISSUE 13

Welcome to Issue 13 of the *IfM Review*.

It might be a surprise to some readers to learn that our cover and feature story in this issue is about healthcare. What does the Institute for Manufacturing have to do with healthcare? Quite a lot, as we continue to find out, and not just in relation to COVID-19.

As I say in our lead article, healthcare is a manufacturing sector, in the same way the aerospace or automotive sectors are. It is a sector we have been working with for many years in many different areas, from medical device design and pharmaceutical supply chains to hospital logistics and management.

The past two years have opened the eyes of all of us at the institute to just how much our IfM approach applies to healthcare, and the possibilities for new solutions when we look at healthcare issues in new ways.

So it is wonderful to be able to explain more about the IfM approach to healthcare, along with my colleagues Jag Srai and Ronan Daly, and to feature some of the great recent work we have done and are intending to go on doing in this sector.

Rob Glew explains how we are taking the lessons in logistics that we learned while running the University of Cambridge's student COVID-19 testing programme and applying them to other contexts. Carl-Magnus von Behr discusses our recent work in facilitating better information sharing among NHS trusts. We explore Veronica Martinez's work, which looks at how the right business model is essential to the effectiveness of a new medical device. And the team in our Fluids in Advanced Manufacturing group gives us an update on their work on affordable and accessible ways to manufacture important health tests.

Beyond healthcare, our latest issue is filled with more of the latest exciting work from across the institute, spanning our technology, management and policy activities.

Among our articles, Lili Jia analyses how food manufacturing can improve to reduce food allergy incidents. Frank Tietze examines how SMEs can use their intellectual property more strategically. And Veronica Martinez examines the value of digital twins to the aerospace sector.

Elsewhere, Duncan MacFarlane contributes an intriguing account of the origins of the Digital Manufacturing on a Shoestring project which is helping smaller manufacturers to digitalise by using low-cost, simple digital solutions.

There is an update on the IfM-led Cambridge hub of the EIT Food Accelerator Network, which offers expert mentoring and is helping agritech and foodtech start-ups across Europe.

And there are new stories from our knowledge transfer company, IfM Engage. We introduce our latest membership group, the Sustainability Association and Dr Imoh Ilevbare explains why he loves helping organisations to create their own roadmaps. The policy team is featured with Jennifer Castañeda-Navarrete's analysis of the impact of Industry 4.0 on developing countries and Liz Killen's report on STEM skills in the UK civil service.

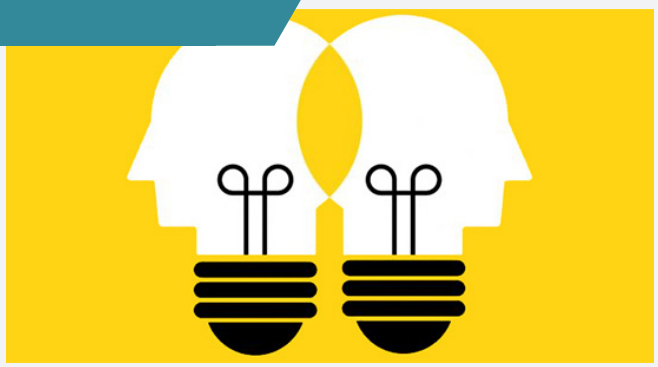
There is much to celebrate as well. Our own Alan Thorne was named a deserving winner of the University's Pilkington Prize for excellence in teaching. Jag Srai and Duncan MacFarlane were recognised with the Vice-Chancellor's Research Impact and Engagement Awards. And our Postdoctoral Awards have allowed us to recognise the excellent contributions of our IfM colleagues to research, teaching and academic citizenship.

As always, I very much hope that this review of our recent work will inform and inspire, and that you will continue to support us as we work to help manufacture a better world.

Best wishes,

Tim Minshall
Dr John C Taylor Professor of Innovation and Head of the Institute for Manufacturing

NEWS



IFM PARTNERS ON NEW HUB TO DRIVE HEALTHCARE INNOVATION ACROSS CAMBRIDGESHIRE AND PETERBOROUGH

With support from the IfM, Cambridgeshire and Peterborough will host one of four new UK hubs for innovation and improvement in healthcare, as part of a national programme from The Health Foundation to ensure that people using services benefit faster from effective healthcare technology and practice.

The winning bid is led by the Cambridgeshire and Peterborough NHS Foundation Trust (CPFT), with joint leadership from Cambridge University Hospitals NHS Foundation Trust (CUH) and the Eastern Academic Health Science Network (AHSN).

It was co-produced with patient and citizen groups in partnership with NHS trusts, local authorities, universities, primary care alliances, and innovation partners, including the IfM, to assist the developing Integrated Care System. The new hub will provide expertise and support to adopt innovations which can make a positive impact on patients and quality of life, as well as tackling health inequalities.

Tim Minshall, Dr John C Taylor Professor of Innovation and Head of the Institute for Manufacturing, said: 'It is wonderful that Cambridgeshire and Peterborough will become the site of a new innovation hub. The IfM is proud to support colleagues from across the local healthcare system in embedding innovation throughout the region.'

Tracy Dowling, Chief Executive of CPFT, said: 'I'm delighted that our collaborative project has been awarded funding to build this resource for the Cambridgeshire and Peterborough health system. Thank you to everyone who contributed to the bid, sharing your expertise, insight and time to make it a success. We need to ensure we are applying the best innovations to improve lives and care as quickly as possible, working with clinical, innovation, academic and public partners.'

IFM PLUGS INTO NEW MADE SMARTER INVESTMENTS IN SMART MANUFACTURING

IfM is partnering on multiple strands of a new £53 million investment in smart manufacturing and connected supply chains from UK Research and Innovation (UKRI) and Made Smarter.

Leading the IfM contributions will be partnerships in two new Made Smarter Innovation research centres.

The Digital Medicines Manufacturing Research Centre, led by the University of Strathclyde with partnership from Loughborough University and the University of Cambridge, will accelerate the adoption of industry digital technologies across the pharma sector to transform medicines development and manufacturing productivity and drive patient-centric supply.

The Research Centre for Connected Factories, led by the University of Nottingham, with partnership from the University of Sheffield and the University of Cambridge, plans to develop new digital manufacturing infrastructure that can autonomously adapt into different configurations to meet specific product and volume requirements, supply chain variations and disruptions.

The research will provide a blueprint for a unique connected network of future smart factories able to cost-effectively manufacture complex products on demand, while exhibiting new levels of resilience and responsiveness to rapid and unpredictable change.

As part of the funding awarded from Made Smarter, the IfM will also be undertaking collaborative research as part of the SmartPSC project, where the application of digital technologies will be applied to integrate the pharmaceutical manufacturing supply chain and enhance efficiency, productivity, flexibility, resilience and sustainability.

In addition, the institute will lead on one of several flagship projects of the new Made Smarter Innovation Digital Supply Chain Innovation Hub, focusing on just-in-time medicines supply.

IFM WORKS WITH DOMINO PRINTING TO IMPROVE PERFORMANCE IN CONTINUOUS INKJET PRINTERS

The IfM has worked with global printing company Domino to help optimise ink designs for different production environments.

The collaborative venture, which looked at the jetting process in continuous inkjet (CIJ) printing systems, paves the way for more efficient and sustainable printing processes and consistent, reliable print quality.

Dr Cristina Rodriguez Rivero worked with researchers in Domino to study the jetting process of CIJ printers at the micro level. By looking at how to tackle particle build-up of CIJ printers – which can lead to frequent cleaning and subsequent downtime – the project has led to a better understanding of why particle build-up occurs, and how to overcome it.

'By running a series of high-speed experiments using illuminating lasers and smoke to observe build-up, the project has provided insights to help Domino optimise ink designs,' said Dr Josie Harries, Group Programme Director, Domino Printing Sciences.

'It has also allowed us to explore where we can develop in-house capabilities, similar to the visualisation techniques employed by the IfM, so that we can conduct further research as part of new ink development processes. That way, we can continue to provide reliable solutions for our customers in the future, as and when new production processes arise.'

Dr Ronan Daly, Head of the Fluids in Advanced Manufacturing research group at the IfM said: 'Our work with Domino Printing shows how collaboration can lead to real industrial impact. There is a long history of advanced imaging at IfM to help build further scientific understanding of manufacturing processes. We hope our work with Domino will contribute to their printer design process and add real value for customers.'

IFM INNOVATION METHODS ENABLE NEW APPROACHES TO ADDRESS DEPRESSION IN YOUNG PEOPLE

IfM Engage practitioners have contributed to the report *Changing Hearts, Changing Minds*, which proposes new evidence-based approaches to the prevention, diagnosis and treatment of depression in young people.

Decades of research at the IfM's Centre for Technology Management have resulted in the development of methods for managing the innovation process, which have been successfully used with hundreds of industry partners. The same methods are now being used to help join up the fragmented landscape of young people's mental health research and practice.

These methods have helped to develop a multidisciplinary understanding of how depression develops in young people, outlined in the report published by The William Templeton Foundation for Young People's Mental Health (YPMH).

The report also offers specific opportunities for early intervention, including prevention, prediction, detection, diagnosis and treatment, as well as exploring how these opportunities can be applied to self-care by individuals and their families, the formal healthcare system and the wider mental health support ecosystem.

The report is part of a two-year project funded by the Engineering and Physical Sciences Research Council (EPSRC), part of UK Research and Innovation. The project explores the configuration and use of the IfM's strategic technology and innovation-management research in complex healthcare applications.

The report is an output from a case study that engaged a wide range of participants, including researchers from social, biological and psychological disciplines related to depression; research knowledge transfer specialists; clinicians from general practice, clinical psychology and psychiatry; industry, such as diagnostics and nutrition; mental health support charities; school mental health support specialists; and young people and parents.

Using the methods developed at the IfM's Centre for Technology Management, IfM Engage practitioners engaged the participants in a collaborative process to develop a more joined-up understanding of the social, biological and

psychological mechanisms by which depression develops in young people, and to generate and evaluate ideas for prevention, prediction, detection, diagnosis and treatment.

Dr Jon Wilson, Consultant Psychiatrist for Central Norfolk Youth Service, Norfolk and Suffolk NHS Foundation Trust, said: 'This groundbreaking project shows us a better future in which we may be equipped to not only treat but also reduce, and even prevent, the development of this increasingly prevalent, debilitating and often devastating condition. It brings a fresh approach to the challenge by using engineering and innovation management methods to engage a broad spectrum of clinicians, academics, mental health charities, schools, industry and young people and their families.'

The IfM, IfM Engage and YPMH are collaborating with Aviva Health to understand what needs to be done to translate the ideas for innovations identified in *Changing Hearts, Changing Minds* into practice. The project is engaging stakeholders from across the mental health ecosystem in consultations and workshops to identify approaches to enable change, identify key barriers and enablers, and widen understanding of the approach and the opportunities it offers to improve well-being.

Scan the QR code to find out more and to download the full report.

IFM RESEARCHERS RECOGNISED IN 2021 VICE-CHANCELLOR'S RESEARCH IMPACT AND ENGAGEMENT AWARDS

The IfM's Jag Srai and Duncan McFarlane have been recognised in the 2021 Vice-Chancellor's Awards for Research Impact and Engagement.

Dr Jag Srai is a team member of the TIGR2ESS research group which won the Collaboration Award. The research group (which spans three schools: biological sciences, technology and humanities and social sciences) seeks to transform India's green revolution by research and empowerment for sustainable food supplies.

Professor Duncan McFarlane was named as a runner-up in recognition of his work with senior clinical and management teams within local hospitals to implement effective and collaborative ways of working during COVID-19.

The Vice-Chancellor's Awards for Research Impact and Engagement recognise outstanding achievement, innovation and creativity in devising and implementing ambitious engagement and impact plans, which have the potential to create significant economic, social and cultural impact from, and engagement with, research.

MAKING AN IMPACT AT DIGITAL MANUFACTURING WEEK

Last November, thousands of manufacturers, industry leaders and technology providers descended upon Exhibition Centre in Liverpool for Digital Manufacturing Week 2021.

Produced by *The Manufacturer* magazine, Digital Manufacturing Week (DMW) is a national festival of advanced manufacturing. The IfM works with *The Manufacturer* all year-round providing content on the latest research for the magazine, and DMW offers the opportunity for the institute to hear about the latest industry trends in digital manufacturing, reconnect with partners and engage with new organisations.

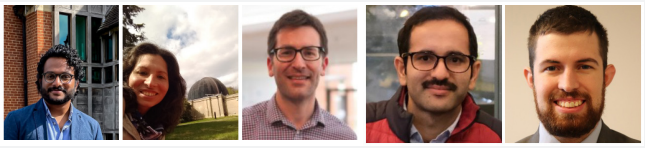
As official knowledge partner for the event for a fourth year in a row, the IfM delivered a packed schedule of masterclasses, keynotes and live demonstrations – all designed to help delegates unpick the key business challenges of today.

With a dual-aspect exhibition space, a dedicated IfM networking space and the IfM Theatre, the IfM team, accompanied by experienced industrial associates and researchers, had a strong visible presence and were on hand to provide expertise on the latest research and insights into digital challenges.

Six IfM strategic masterclasses hosted by IfM Engage covering innovation strategy, automation assessment, technology acquisition, roadmapping, AI and Industry 4.0, were held in the IfM Theatre across both days by IfM experts.

At the Smart Factory Expo, Digital Manufacturing on a Shoestring set up a mock-factory production line with live demos showing how low-cost digital solutions could help improve efficiencies on a simulated gearbox production line.

Three shoestring solutions were demonstrated and the Shoestring team spoke with over 100 manufacturers who were keen to find out how to add low-cost technologies to their existing production lines. The team also met with technology providers keen to make their low-cost kit compatible with Shoestring, as well as regional business innovation teams who were excited to see how Shoestring could help facilitate, quickly and easily, more digitalisation in small- and medium-sized companies in their regions.



IFM POSTDOCTORAL AWARDS 2021

Congratulations to our 2021 IfM Postdoctoral Award winners for their excellent contributions to research, teaching and academic citizenship.

This year's award winners are:

Excellence in Research
Dr Manu Sasidharan
Dr Vinod Kumar Chauhan

Excellence in Teaching
Dr Etienne Rognin

Excellence in Academic Citizenship
Dr Cristina Rodriguez

Highly Commended: Dr Greg Hawkridge

The IfM Postdoctoral awards were established in 2019 in recognition of the vital role that postdocs play in driving research and innovation, delivering teaching, and contributing to the academic community.

THE UK INNOVATION REPORT 2022

The findings from the 2022 edition of the *UK Innovation Report* are now available, incorporating updated and new data, new angles on policy questions, and new sector-level analyses of the pharmaceutical, automotive and renewable energy sectors.

Scan the QR code to download the full report.

OI FORUM'S ANNUAL COMPETITION FOR FOOD-SECTOR SHOWCASES INNOVATIVE SOLUTIONS TO SUPPORT SDGS

Entrepreneurs from around the world took part in the 10th Open Innovation (OI) Forum's annual Food, Drink and FMCG competition to pitch solutions to support the UN's Sustainable Development Goals (SDGs).

On 7 December 2021, 22 entrepreneurs pitched to an influential panel of decision-makers from major companies including Mars, PepsiCo, Suntory, Muller, Cargill, Boots, Twinings, Yili and Kerry. The innovative solutions focused on four of the UN's SDGs that are central to the food and drinks sectors: Zero Hunger, Good Health and Wellbeing, Responsible Consumption and Production and Climate Action.

Selected finalists were invited to a follow-up session the next day to participate in 'hackathons' with forum members to explore routes to scale and leverage their solutions.

For a full list of the 2021 winners and for more information about the OI Forum, scan the QR code below.

NEW REPORT EXPLORES THE BENEFITS OF DIGITAL TWINS IN THE SATELLITE INDUSTRY

In a newly released report, *Digital twins: Thought leadership in the satellite industry,* Dr Veronica Martinez and Nicolai Huss consider the design, implementation and potential benefits of digital twins in the satellite industry.

Following on from previous work on the importance of digital twins to digital transformation in the aerospace industry, this briefing now considers their application in space, building the first roadmap for both strategic design and technology management in the space industry.

The results represent a significant advance in the understanding of the potential for digital twin applications in the satellite sector, bridging the gap between company strategy and technology. The report establishes a strategic need for digital twin implementations and presents market drivers, different digital-twin based services, the implementation process, the resources needed and the potential risks.

'There is a strong strategic desire to provide value-added services in the space industry, driven by changing market conditions towards flexibility and digitalisation,' says Dr Veronica Martinez, co-author of the report. 'Digital twins offer value on an operational level, through things like predictive maintenance, on a communication network and security level, for example through modelling threat management, and on an integrated systems level, combining different satellite constellations into one network.'

The report also defines the challenges to implementing and realising the benefits of satellite digital twins, including a lack of cultural acceptance and cyber security challenges. Skills also present a challenge: in the future, firms seeking to compete by developing digital twins will require a digitally enabled workforce equipped with both technical expertise and a strategic, data-driven mindset.

'We're working in an era where digital and data technologies are having a real impact on so many areas of our business and lives – digital twins being one,' says Dr Jon Hall, Chief Technology and Innovation Officer of Babcock International Group, who contributed to the report. 'This means it is less about the twin creation and more about the adoption of digital twins in businesses to create real value in better asset performance.'

The report and accompanying roadmap were completed with contributions from Babcock International Group, the Karlsruhe Institute of Technology, and the UK National Space Agency.

The full report is now available to download via the QR code below.

IFM EMBARKS ON NEW COLLABORATION TO REVOLUTIONIZE MULTI-TIER SUPPLY CHAIN RISK SENSING

The IfM is collaborating with technology company Enspan, AML Sheffield (an aerospace manufacturer) and the Manufacturing Technology Centre, together with industry partners, to help UK manufacturers address the challenges of supply chain risk prediction.

It's estimated that disruptions to supply chains in 2020 cost companies £2-£3 trillion, exposing the complexity and interdependence of global supply chains that have accumulated over recent years. Thanks to 12-month funding from Innovate UK, the Collective Supply Chain Resilience project (CORES) aims to equip manufacturers and their suppliers with the tools to address the challenge of supply chain risk prediction and, as a result, to avoid the disruptions and costs associated with them.

'Supply chains are complex networks of interdependent organisations. Typically, when predicting disruptions and deciding on mitigation strategies, organisations act alone, rather than as a chain,' explains Alexandra Brintrup, Associate Professor in Digital Manufacturing and leader of the Manufacturing Analytics Research Group at the IfM.

'Studies have shown that increased data-sharing and collective decision-making would increase resilience, a key factor in allowing companies to deal with uncertainties. We believe that new, machine-learning based approaches could make a prediction of risk more accurate and timely.'

CORES project

According to Tim Andrews, Lead Advisor in Digital Transformation at the Manufacturing Technology Centre, collective approaches to risk prediction in supply chains have not been feasible thus far due to organisations' reluctance to share data with one another for fear of opportunistic behaviour and due to lack of independent, easy to use tech solutions.

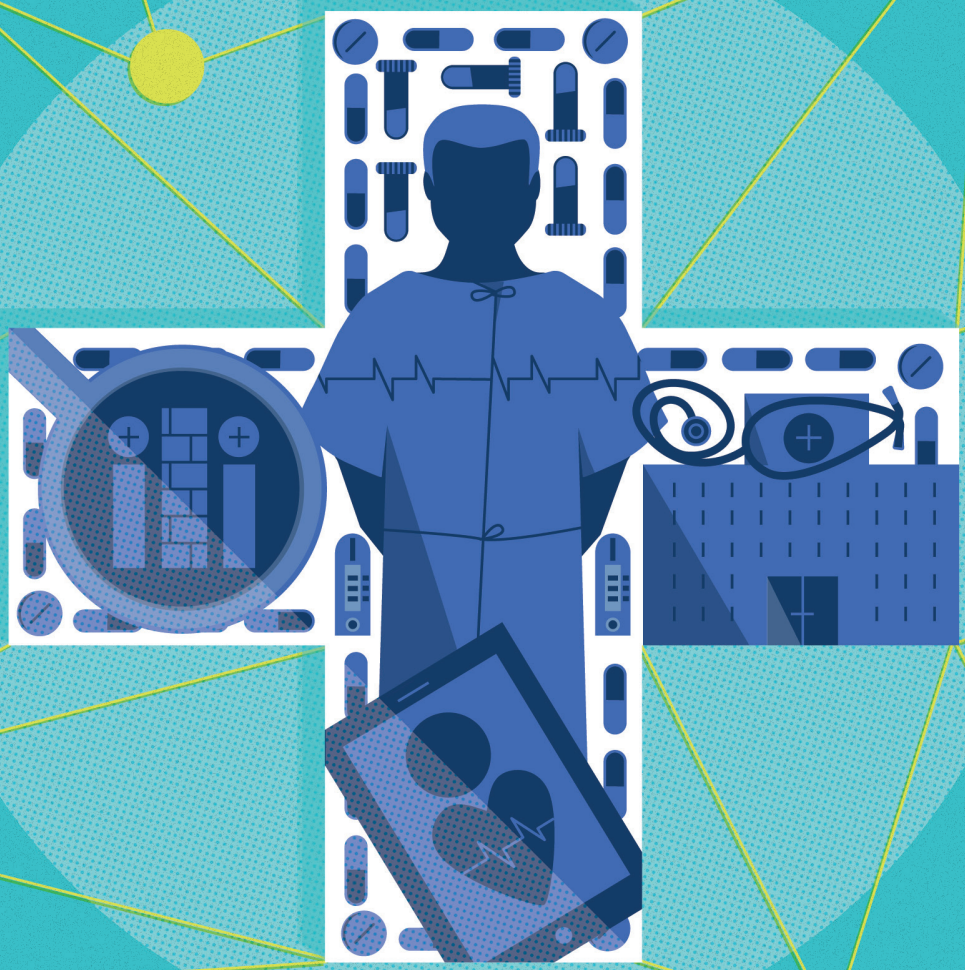
'The project will use emerging machine-learning approaches in the artificial intelligence field that may help supply chain members collectively optimise resilience while keeping their data private, by predicting both supply-side and buyer-side risk. The approach enables organisational agents to collaboratively develop a shared risk prediction model. As the approach can be automated, the costs of manual orchestration are avoided,' says Tim.

Using Enspan's technology to enable ecosystem-wide data processing, IfM will bring its academic research and knowledge in the area of machine learning to jointly develop and test a completely new way of predicting disruptions – using large sets of historical transactions for the entire supply chain, and to derive business insights to enable timely and appropriate mitigations.

Enspan will deliver the technical and data-management aspects of the project (for inputs into and outputs from the algorithm), business application of the algorithm, and project administration. IfM will lead the algorithm development and testing. AML, supported by the MTC, will contribute business requirements and validate outputs of the algorithm within its supply chain.

Together, the project partners expect that the project will achieve the scale necessary to significantly make the UK's supply chains more competitive.

To find out more about the project, please visit:
www.projectcores.com



FROM IDEA TO PATIENT: THE IFM APPROACH TO HEALTHCARE

The IfM has been working on research in healthcare for over thirty years. When the COVID-19 pandemic hit, this meant the institute could respond to new challenges using past experience. Now, the IfM is building on that work across its research and practice.

Over the past two years, the IfM has been recognised for its work in response to the COVID-19 pandemic – helping local hospitals to make the best use of their resources, streamlining logistics for sourcing and storing vital personal protective equipment (PPE), informing decision-making on emergency demand, and developing a ventilator sharing system to be used in emergencies.

While these challenges were new, IfM involvement in healthcare was not. The pandemic response built upon three decades of research across healthcare-related areas – work that is, according to Tim Minshall, Dr John C Taylor Professor of Innovation and Head of the Institute for Manufacturing, firmly part of the manufacturing landscape.

'Healthcare is a manufacturing sector,' says Tim. 'We need medicines and medical devices, and they need to be developed, produced, delivered effectively. Healthcare services also need to be supported to operate as efficiently and effectively as possible. Our work on healthcare mirrors our view of what manufacturing really means.'

Today, IfM healthcare research projects range from clinical trial supply chains through to the manufacturing of drugs and medical devices, all the way to developing service models and reconfiguring healthcare supply chains.

'Some of the early work we did has been around pharmaceutical supply chains, exploring how you ensure that drugs in all forms reach patients in the most effective way,' Tim explains. 'Our research started in that field at our Centre for International Manufacturing more than ten years ago.

'Another key area of work is on medical devices: building things that are needed within the healthcare system. This can be anything from medical robotics, which we were involved in as early as the 1990s (in fact, we even spun out a company called BioRobotics looking at systems designed specifically for using the healthcare sector), to low-cost diagnostics.

'More recently, there has been the idea of applying operations management to different sectors, and this relates to some of the earlier work of Professor Duncan McFarlane, where he took all those principles of operations management and applied them to a hospital setting – looking at a hospital's inputs, outputs and flows and treating the healthcare system as an operation that needs to be optimised.'

An emerging fourth area is innovation and the role of research in complex systems change; for example, exploring how innovation methods used by industry can address depression in young people. A rather surprising route, at first glance, for industrial engineers.

'I think it surprises people that the Institute for Manufacturing is involved in young people's mental health work,' says Tim. 'They ask: How does that fit into this logic? Well, the answer is because we understand how to support successful innovation. We understand how difficult it is to get a complex system to change.

'Fundamentally, at the Institute for Manufacturing, we are interested in developing processes to enable positive change in complex systems – and healthcare provides a huge range of urgent and important challenges for us to help address.'

Manufacturing and medical device development

The regulatory questions that come with medical device development reflect these complex challenges. For Dr Ronan Daly, Head of the Fluids in Advanced Manufacturing research group at the IfM, considering those questions at an early stage of development for emerging technologies is vital – and an area where the IfM is well placed to advise.

'If you look at healthcare, if you look at medical devices, the regulations that govern the manufacturing of medical devices cover everything from the design through to the instructions for the user,' says Ronan.

'What manufacturing really does is cover the complexity of physically making a medical device in the factory and also, then, the design of what is included in that, and how it will be used. The manufacturing readiness levels, and questions that come along the way, depending on the answer, could change entirely how you would design an original device.

'The IfM is helping with the fundamental research around the technology and devices, but also working on the effects these will have throughout the manufacturing process.

'For example: Have you thought about how you're going to sterilise your medical devices? There is actually a change to the fundamental chemistry as you sterilise them, so the function won't do what you expect, or the flows of the materials while you're dispensing them into the body might change the function of the thing you're putting in there,' explains Ronan.

'By co-developing the manufacturing questions at the same times as science, we're helping get to an optimum design quicker, and therefore getting to patients quicker.'

Manufacturing excellence and expertise

Dr Jag Srai sees the 'through to patient' outlook as an essential part of the IfM's work.

'We see in our work with both hospitals and on drug development how that complex system goes all the way through to the patient,' says Jag, who heads the Centre for International Manufacturing at the IfM and leads on the IfM's healthcare theme.

'Active ingredient production, product formulation, packaging, and then the packing involves multiple manufacturers in multiple geographic locations. This front-end of the supply chain then leads into a very complex distribution system eventually reaching through to the patient and all the service models around that – these are all things the IfM has expertise in, that we can apply to the healthcare space.'

Jag also believes the IfM's work in this field is important for the wider Cambridge ecosystem and the UK economy as well.

'The UK invests significant funds in drug discovery and is widely recognised for its leading position in this area, but the location of manufacturing is often influenced by local incentives leading to a very complex global manufacturing footprint,' says Jag.

'So, whilst the UK has a leading position in the discovery space – and is home to two of the largest multinationals in GSK and in Astra Zeneca – and a thriving healthcare innovation cluster, most essential medicines, or off-patent generics are imported from distant contract manufacturing organisations. This introduces significant risks to security of supply.

'We therefore have this legacy, that product discoveries are often UK-based, but then we typically don't make the product here, due to scale economies, incentives, or infrastructure provision. New production technologies and supply security considerations are driving a rethink on manufacturing location decisions of the past decades and providing new opportunities for value capture.

'So I think it's important that Cambridge especially is known for not just discovery, but also manufacturing excellence and supply chain expertise.'

COVID-19 mobilisation

It was this strong foundation in healthcare work – together with the institute's culture of collaboration - that meant the IfM was able to react quickly and effectively to the COVID-19 crisis, mobilising students, staff and healthcare contacts across the city to ensure a swift and targeted response.

'We were able to respond so quickly to COVID-19 partly because of our open culture, but also the expertise we were able to access,' Tim Minshall explains. 'Addenbrooke's Hospital reached out to us in the middle of a crisis, and we wanted to respond as positively as we could. The engagement with the hospital was helped by a sense of a common cultural approach, a similar sense of purpose, and a shared context of our local community: we all had, at some point, made some personal link with the work of our local hospital. This helped ensure a ready level of engagement at the institute, as well as the individual level.'

With many hospitals across the UK needing rapidly accessible and innovative solutions to operational challenges arising in the COVID-19 crisis, the IfM team addressed the areas of hospital logistics, PPE delivery and intensive care unit (ICU) equipment development.

'The hospital said our engineers brought diversity of perspective to addressing multiple challenges. As a result of the success of this work, a joint Cambridge University Hospitals Trust (CUH)–IfM panel has been initiated so that the local hospitals and the IfM can continue working together for mutual benefit after the pandemic,' says Tim.

The future of healthcare at the IfM

Devastating though it has been, COVID-19 has shone a light on the workings and failings of the healthcare-related parts of the manufacturing world: 'Numerous cracks in our healthcare systems had been appearing way before the pandemic,' says Tim. 'COVID-19 hammered a wedge into those cracks and revealed how alarmingly fragile these systems are. But it also showed us that things could be done differently, and it accelerated the development of exciting ideas that had been lurking in corners for years.'

The IfM is now spinning out lessons from COVID-19 across its healthcare activities. Experiences during the pandemic have led to research in knowledge-sharing across the NHS and how to apply logistics of testing programmes to other healthcare and humanitarian contexts, among other work.

Meanwhile, researchers across the institute are building on that established healthcare foundation, for example, examining service models for new wearable devices to treat cancer in children, improving targeted drug delivery, and developing new low-cost medical sensors.

'In some cases, healthcare can be a unique challenge, with additional concerns about things like regulation and patient safety. But often the common principles from our work in a range of manufacturing sectors that the IfM works in, apply in a very similar way,' says Tim. 'This is especially true when we are looking at solutions that work not just in the UK but in many different healthcare contexts across the world – we need simple, efficient and effective solutions. That's what COVID-19 really highlighted, and what we are continuing to pursue in our healthcare work.'

To find out more about IfM healthcare research and practice, scan the QR code below:

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LESSONS FOR EMERGENCY HEALTHCARE LOGISTICS

IfM PhD student Rob Glew, supervised by Professor Duncan McFarlane, reflects on the lessons learned from two years of working on emergency healthcare logistics during the COVID-19 pandemic. A new research project with ETH Zurich is applying these lessons to the Ugandan healthcare system to build resilience for future emergencies.

Logistics formed an important part of our COVID-19 response at the IfM. An IfM team ran an emergency PPE warehouse for Cambridge University Hospitals early in the pandemic, and later we coordinated the pooled PCR testing programme for the whole of the University of Cambridge.

We're now taking the lessons learned from two years of work and research in emergency healthcare and delivering them to a new location. In collaboration with the team at ETH Zurich, led by Professor Stephen Wagner, we're working with the Ugandan Ministry of Health to improve their logistics preparations for medical emergencies.

Infectious disease outbreaks are frustratingly common in Uganda, particularly in its remote and rural regions. The Ugandan government is working with the IfM and ETH Zurich to create a new strategy for logistics preparedness by placing medical supplies in key locations and planning emergency transport to rural areas.

Our experience with COVID-19 testing in Cambridge is directly informing the plans to create temporary healthcare logistics in emergencies in Uganda. Drawing on what we've seen during COVID-19 and bringing it to a new environment, we have identified three critical lessons for emergency healthcare logistics.

Complexity kills, so kill the complexity

When healthcare logistics are planned in a high-pressure, emergency situation, it is easy to overlook the complexity of the system that's being created. For example, distributing PPE in the early stages of the pandemic became very complicated very quickly, with the military, the NHS, local authorities, and many others all involved in different roles.

Complexity makes adapting to changes more difficult, because it is hard to understand the effect of changes through the logistics network. The first step in killing complexity is to map out the emergency network, then to start to remove the links between organisations that aren't required for the network to function.

Standardise to prepare for unknown changes

Working in a state of flux has been the norm rather than the exception for emergency healthcare logistics during the COVID-19 pandemic. It's especially difficult to manage changes when they arise suddenly with little or no time to prepare. Yet, one way to get ready for possible but unknown future changes is to 'standardise the interfaces' in the logistics network.

In the University's COVID-19 testing programme, this meant delivering all test kits to colleges in identical transport boxes. The standard interfaces allow internal changes to be made to the logistics operations without affecting those on the outside.

Look for the tipping point

Scale is particularly important for healthcare operations, especially during infectious disease outbreaks. As demand increases, the experience will not be the same across the network. Some regions, for example, may experience more intense disease outbreaks than others. At the same time, the spare capacity for scaling up will also be different across the network.

These two effects combine to lead to a tipping point at one node in the network, where the combination of demand and available capacity will first reduce the ability of the logistics operations to scale up. Preparing for emergencies requires scenario planning to identify these 'tipping points' and evaluating the options for expanding them if required.

Common lessons

There have been a great many specific challenges related to COVID-19 over the past two years. But in identifying these broader lessons that can be learned, we're now preparing to use the experience to inform new healthcare and humanitarian logistics solutions.

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HOW CAN KNOWLEDGE BE SHARED BETTER ACROSS THE NHS?

Building on experience from the COVID-19 response, IfM PhD student Carl-Magnus von Behr explains how new research is looking at knowledge-sharing across NHS trusts.

At the beginning of the COVID-19 pandemic in March 2020, we were invited by the Cambridge University Hospitals NHS Foundation Trust to look at their infrastructure for providing oxygen to patients and how we could help to improve it. We worked closely with their estates department and external advisors, learning about how they understood the system, and identifying if there were things that could be done better.

We soon discovered that knowledge-sharing across NHS trusts was not always effective and, with more than 200 trusts across England all responding to COVID-19, that there was an opportunity to make improvements.

Estates and facilities management departments are unique because they don't feel like they're normal estates people in a normal estates organisation. For example, you wouldn't have oxygen pipelines in a normal building. Most hospital trusts have a unique building context and infrastructure context, so, even with shared challenges, they often feel like they don't have much knowledge or information they could share with others.

And with the NHS being so large and geographically dispersed it is even more complicated. It's a complex adaptive system – you have a lot of parts that are working towards one goal but they are all responsible for their own part, and all adapt themselves individually rather than having one strategy that combines them all.

In the NHS, the barriers to knowledge-sharing are very broad and there are a lot of them. And many of them relate to the fact that the NHS keeps changing all the time. They are in the process of constant change with reorganisations and new five-year plans which overthrows a lot of infrastructure that enables knowledge-sharing.

What I'm looking at in detail at the moment is the role of organisational trust in knowledge-sharing – not only the interpersonal trust between colleagues based on previous interactions, but also employees' trust in organisational structures and processes. This aspect is referred to as impersonal or institutional trust and is vastly influenced by how much the organisation changes.

There is a lot of expertise in healthcare in the IfM but less expertise on the estates side. My advisor, Professor John Clarkson (Engineering Design Centre), brings in the expertise in the healthcare systems engineering and looks at all those complex layers of the NHS. We have combined that with the open innovation knowledge that we have here at the IfM to look at this more closely.

Estates managers are very aware of the deficiencies in knowledge-sharing but they don't have time to participate in any research because they have other urgent issues, such as a roof coming down, for example. And the same applies to the sustainability challenges they are facing. If they are repairing a roof, how are they are meant to focus on net-zero carbon targets?

This was a big issue when we looked at the oxygen infrastructure in Addenbrooke's Hospital. We had various ideas, which couldn't be implemented because the system runs 24/7. You can't just stop the oxygen pipeline to, for example, integrate an invasive flow meter so that you have a better visibility of the oxygen flow in the building. The need for business continuity, or operational continuity, slows everything down. So you need to explore other options that you wouldn't have to in other sectors. In the end, we went with a non-invasive flowmeter, which is more expensive and, yes, just a bit more complex, but it worked.

I'm now looking at case studies on hospitals in every different region across England to investigate the flow of information about the oxygen systems during COVID-19. We want to understand what pieces of information got to which parts of the country and to which levels of the NHS, and then how they ripple down to the hospital so that we can see what barriers actually stop urgent knowledge reaching the people that it needs to reach.

We are trying to raise awareness that you need to build trust among employees and trust in the organisation. And then you can work on the knowledge-sharing. We are trying to enhance the understanding of that complexity, and hopefully helping to improve the exchange of knowledge.

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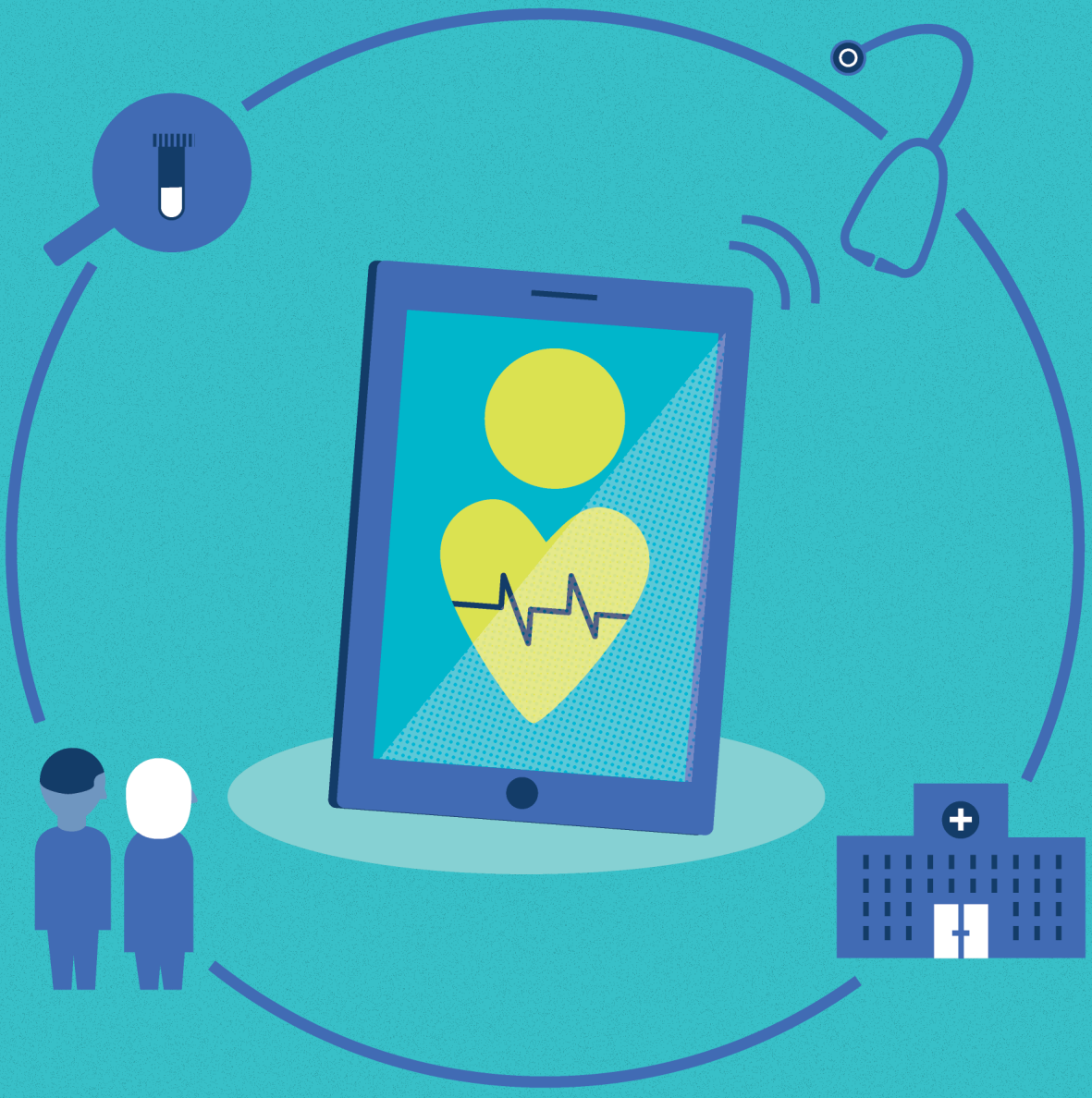
PUTTING NEW HEALTHCARE TECHNOLOGY TO EFFECTIVE USE: WEARABLES FOR THERAPEUTIC CANCER TREATMENT



The development of cutting-edge wearable technologies that can monitor people during their cancer treatment is transforming our understanding of the disease and our ability to detect and treat it. But integrating such new technology into care is essential to its effectiveness.

Dr Veronica Martinez and her team at the IfM's Cambridge Service Alliance are currently investigating a proof-of-concept for a therapeutic treatment of childhood cancer. The wearable device works by separating and changing the form of the immune system's T cells with small electric shocks generated by the user's own body heat and movements.

Veronica's research has focused on how patients – and all those involved in their care – might cope with these kinds of wearable technologies and ensure that their use in service delivery is patient-centric.

'Healthcare delivery is highly complex. It comprises layers of processes [as well as] a network of patients and partners, delivery models, and regulatory requirements,' she says.

'These complexities, when combined with technological advancements, can prevent new technologies from being accepted and used effectively. Many devices end up being useless because the hospitals don't know how to use and integrate them into their existing operations and systems.

'So, with this research, we are focusing on the user element – not just the patient but also the nurse, the doctor, the clinicians, the haematologists, the director of IT, even the hospital trust. Every one of these stakeholders needs to understand how this device will be creating value.

'With these devices, it's not just about how to collect data, but what you do with it and what kind of messages you want to send to all those involved. Who has the information and how they act is crucial to its effectiveness. Our research acknowledges that the development of technology has to have the user in mind. We don't just need to develop the technology, but also need to understand how it will be developed and used.'

Child healthcare involves a lot of people, including patients and their family, oncologists, physicians, nurses, and other hospital employees. Veronica and her team interviewed people at all these points of the process in order to develop workable business models for the device.

'Our research is the first to present a business model framework for therapeutic devices by elaborating on the benefits and challenges of product–service systems with the list of pros and cons of each scenario, and by considering not only the levels of business model and tactics but also the level of process,' says Veronica.

By applying the findings to a case study (a wearable device called the Microfactory, which aims to treat children with blood cancer), the research identified the needs of the end-users, the different stakeholders of cancer treatment, the functions of the device and the possible uses.

It also highlighted that the flexibility of connections between the Microfactory's digital system and existing hospital systems is critical for these devices to be successful in the market.

'This type of business model systems thinking can help us understand how one hospital is different from another. It takes all the human elements and helps us understand how wearable devices can be utilised,' says Veronica.

This approach highlighted that a greater focus on services, particularly the user-experience, is needed in order for these devices to be successful.

'Without the right business models, wearable devices can't be used by health services effectively because they won't be developed with the right end-user needs in mind,' says Veronica. 'This approach is patient-centric, offering flexibility to patients and their families, while ensuring the devices can be used to their greatest benefit.'

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NEW MANUFACTURING APPROACHES TO AFFORDABLE HEALTHCARE

IfM research is exploring how important diagnostics and medical devices can be made more accessible to low- and middle-income countries.

Manufacturing healthcare products like sensors and sensitive diagnostic tests can be complicated and expensive, making them less accessible to health systems with fewer resources.

Dr Ronan Daly's team in the Fluids in Advanced Manufacturing group at the IfM have teamed up with Professor Lisa Hall in the Department of Chemical Engineering and Biotechnology to explore ways to make tests more affordable and accessible. They are looking at ways to reduce the complexity of the materials used and how the devices are manufactured, as well as how to manufacture products closer to users, with rapid upscaling and downscaling driven by need.

'Our approach is to look at these products and work with partners in different locations to consider local manufacturing capabilities and materials, and how the manufacturing processes can be adapted to work with available, greener products. By making these devices close to the user, for example, diagnostics like lateral flow tests, and then only needing to distribute locally, we can make them less expensive and thus available to a wider range of people and health systems,' explains Ronan.

One example is biosensors. Normally, these require many steps of biosynthesis or protein manufacture, the transferring and patterning of materials, and designing the process of cell signalling. Lisa's team have built a capability to compress multiple steps into a single process, creating a multifunctional product that can be incorporated straight into a device for disease diagnostics.

'From there, we're working out how to use that process with an affordable technology,' explains Ronan. 'Is it with 3D printing, injection moulding or lamination? What are the simple steps to turn it into a device that is still as accurate and reliable as the earlier, more expensive version? So we're not compromising on use or capability, but finding affordable ways of doing it.'

Lower-cost medical devices

Lisa's team is leading a project where IfM are an integral part, working with the University of Santo Tomas and Ateneo de Manila University in the Philippines to examine how synthetic biology can help to create lower-cost medical devices.

'Many medical devices work by using proteins that can detect the presence of a targeted disease. We're working together looking at how we can use bacteria to create multifunctional proteins, in a process that does not use a lot of energy, is easy to carry out, and gives a product that not only detects a targeted disease but also has an embedded optical signal to let you know that it has been made correctly,' says Ronan.

'It is all produced in a simple vessel, where the proteins are expressed, and engineered with inbuilt colours to show that you have made it to the correct protein. It's really a beautiful thing, and it tells us that it's working.'

The team have been targeting the detection of malaria, dengue, leptospirosis and more recently COVID-19, looking at the sensor development and at economic models, to demonstrate a strong argument for investment.

'We are now looking to take that technique and that approach and apply it to more things and more applications and turn them into real devices,' says Ronan.

Affordability by adapting existing technologies

Another approach to making healthcare affordable is to identify existing technologies that can easily be changed to deliver a diagnostic or therapeutic effect. One possibility that the team are exploring is using touchscreens, found on widely available mobile phones, to do more diagnostic work.

'One of the ways is making it manufacturable at the right place, and the other way we're doing it is trying to find what equipment and tools already exist at these locations, that we can then use. And that was what led us to touchscreens,' says Ronan.

'The penetration into the market of touch screens in low- and middle-income countries is just phenomenal, and they've got built-in computational power. They've got communications. You can coordinate data and send it to whoever needs to interpret it.

'We are at a very early stage of research for this technology and we are looking at the steps we need to take that would make this possible,' explains Ronan. 'This is an example of a potential affordable solution that would make these much more widely available.'

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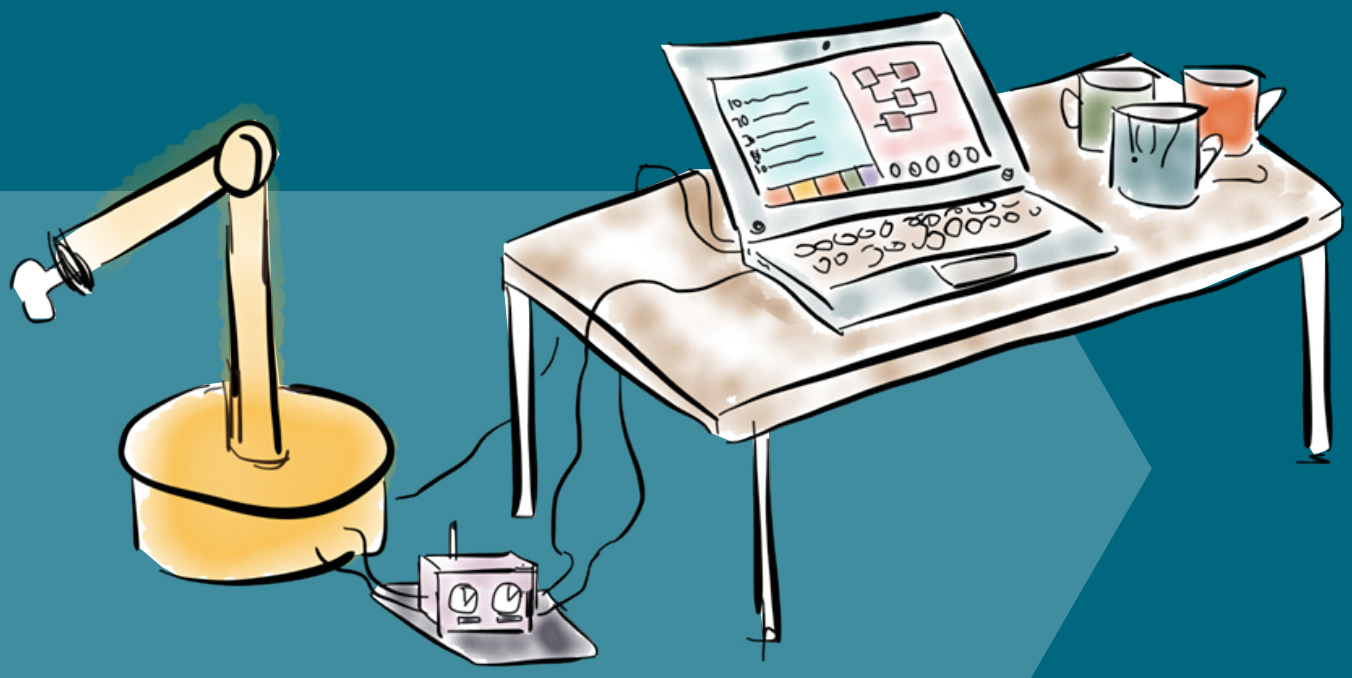
SIMPLER THAN IT LOOKS: DISCOVERING THE SHOESTRING APPROACH TO DIGITAL MANUFACTURING

Four years ago, Digital Manufacturing on a Shoestring was started by a team at the IfM to help smaller manufacturers digitalise by using low-cost, simple digital solutions. Professor Duncan McFarlane, Head of the IfM's Distributed Information and Automation Laboratory and founder of the programme, reflects on how he first realised the potential of this approach, and how they're spreading the word across Britain and around the world.



On a visit to Australia in 2016, I went to a series of Industry 4.0 workshops exploring digital solutions for manufacturing. I spoke with several small companies who told me that the ideas being proposed were all very well, but that they didn't address any of their needs: 'It's too big, it's too expensive, and it's all about new tech. Our needs are much simpler.' These small companies were bewildered by the potential for digitalisation within their organisations and didn't know where to start.

They had a point: Why were all the solutions available to industry so expensive and complicated? Consumer technologies such as phones and cameras and other smart devices were becoming cheaper and more readily available. Why couldn't industry use them? Why couldn't you build something for industry with a GoPro camera and a Raspberry Pi, for example?

Back at the IfM, I scratched my head, and started talking to a number of companies about their needs. And it seemed like there was some mileage in looking into the notion of doing things cheaply and simply for small manufacturers.

At the same time, I began to look at all the older, obsolete automation equipment we had that was too expensive to update, and I started to wonder about how we could deploy cheap equipment and more regularly update our laboratory facilities which our students use.

Then, in early 2017, a student — Chris Barton — came to see me and said he wanted to build a smart fridge in six weeks: a fridge that could sense the age of the produce it held. I told him it wasn't possible, but he disagreed. 'I can get all these cheap components and download some free software on the web and more or less build the whole thing in six weeks,' he said. And he did. That got me thinking... it has taken us years to develop automation projects and yet this student, despite his limited experience, was able to do it fairly easily.

So, the idea of drawing together these different threads around developing very low-cost digital solutions for small companies started to take hold.

The potential was huge. For example, in 2018, a Made Smarter report stated that greater digitalisation of industry could add £455 billion to the UK economy, improve productivity by 25% and increase manufacturing sector growth by between 1.5 -3.0% per annum. But cost, risk, complexity and a potential lack of relevant digital skills were all hampering these efforts.

Building a catalogue of digital solution areas

So in 2018, we established Digital Manufacturing on a Shoestring in partnership with Svetan Ratchev from the University of Nottingham, a number of industrial supporters, and with thanks to initial funding from the UK Engineering and Physical Sciences Research Council (EPSRC). We set about trying to help companies who were really struggling to understand the whole notion of digitalisation, how it applied to them and where they could best benefit.

Simultaneously, we set out to survey and classify all the very low-cost technologies and organise them into a set of solutions to meet the digital solution needs of small manufacturers. Our idea was to assemble solutions from 'building blocks' that could be reused, adapted and combined repeatedly.

Supported by the IfM's excellent lab facilities and our long history within the digital manufacturing realm, we began building prototype solutions that used affordable components. For example, using consumer-grade microcomputers, like the Raspberry Pi and low-cost sensors, all of which could be housed in industrial-proof casing, protected from the factory environment, and combined with user interfaces from open source or other openly available software.

We ran 20 workshops with over 300 companies and talked to them about their business priorities and barriers to growth, and the way in which different digital solutions could help address them. In these workshops, we married priority business needs with potential digital solutions. And from those workshops, we extracted a list of 59 digital solution areas that address the needs of small businesses.

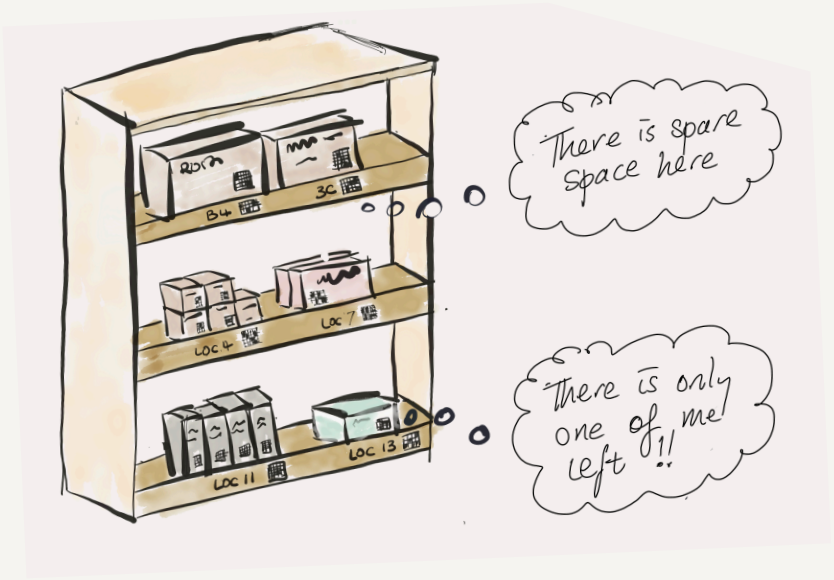
We call this the Shoestring solution catalogue and believe it's the first of its kind. By addressing some of the common operational challenges companies face, the catalogue reduces the need for deep technical understanding and provides a simple, viable route towards digitalisation. And it helps to overcome that understandable initial scepticism – a scepticism not dissimilar to how I felt back when that student first proposed their low-cost smart fridge.

A typical example of a Shoestring solution includes a job tracking system that helps a small company work out where their customer orders are across their shop floor. It sounds very simple, but many companies really struggle to understand when a customer wants to know what state their order is in and where it is at a given time.

Another example is the monitoring of equipment. We've done a lot of work around bolt-on vibration and temperature monitoring systems for pieces of machinery that don't have it embedded.

We also began building a structure that supported real, meaningful engagement with stakeholders – not just industry but national and regional associations, education providers and solution providers. This is to ensure Shoestring has an impact not only within companies but also across the wider manufacturing sector. This encompasses the current and future workforce, as we have found that Shoestring's tools can be adapted to support Further Education Colleges with their education programme and industry engagement, helping to prepare students and apprentices for the world of work, as well as providing invaluable support in industry setting up basic digital solutions during work placements.

Additionally, almost half of the solution areas identified in the Shoestring catalogue can contribute to a company's sustainability goals. For example, by identifying where emissions are generated and by monitoring emission levels, process improvements can be made. Similarly by monitoring energy usage and by capturing data on waste material and energy loss.



Spreading the word

Nationwide support for Shoestring is growing, with industry partners doubling to 56 in the past year.

To date, 14 industry partners have successfully started or completed a pilot with a Shoestring solution and the feedback has been overwhelmingly positive. We've found that once one solution has been successfully applied, industry partners are keen to try the next one.

What we've learnt is that it's about organising and involving a small business in the digitalisation process, rather than just providing them with solutions and hoping those solutions meet their needs. It's about a cultural shift, a changing and opening up of perceptions on how to see digitalisation and its relevance for even the smallest of organisations. Shoestring is not about selling solutions forever. It's about helping SMEs get their toe in the water of digitalisation.

In the last two years, Shoestring has also started to apply its approach into other domains such as healthcare and construction, where the core of the activity is not specifically about manufacturing.

While Shoestring was conceived as a programme to help small- and medium-sized companies, we've also seen that large corporates are also keen to adapt Shoestring to support employee efforts to improve their local digital environment. By adopting the Shoestring approach, teams of employees have a reliable framework in which to develop their own digital solutions, which they can then add to incrementally, and share with colleagues across the company.

In the three hackathons we have run, involving students from the universities of Nottingham and Cambridge, we have been impressed by the low-cost systems that the future workforce can build in two days using the Shoestring approach.

Our live demonstrations of three different Shoestring solutions at Digital Manufacturing Week in November 2021 attracted an enthusiastic response from both manufacturers and regional business adoption teams who could see how Shoestring inspires reluctant, traditional companies to take the first step and try a low-cost digital solution.

The manufacturing of the future

In the next three years, we want to broaden the programme to support self-sustaining roll-outs in all regions of the UK, and provide local support for smaller companies adopting multiple Shoestring solutions.

Using the outputs of the research programme as a starting point, this will involve a regional development approach to support UK regions developing their own local Shoestring programme; an online portal giving users and developers access to the Shoestring configuration platform, pre-configured solutions, training and how-to guides; a community platform and installer directory; and Shoestring training and education programmes for SME manufacturers, service providers, apprentices, trainees and students.

In the longer term, there is an opportunity for Shoestring to have a significant influence on the industrial digital ecosystem in the UK and elsewhere.

It has already been noted that the standards that Shoestring are assembling may in fact form the basis for broader Industrial Internet of Things standards – for which there is little or no current offering. There are increasing efforts to develop similar programmes in Australia and New Zealand, and we've had interest in the Shoestring model from other countries such as the US, India, South Africa and Korea.

Shoestring is really starting to gain momentum. And just like the smart fridge, which was quicker and easier to develop than I could have imagined, our manufacturing partners are discovering that piloting a Shoestring solution is a fast and painless way to dip their toe into the "digital water"!

This article was first published in IfM Insights on 7 February 2022.

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'EXEMPLARY EDUCATOR' ALAN THORNE WINS PILKINGTON PRIZE

The Institute for Manufacturing's Senior Technical Officer, Alan Thorne, has been awarded the prestigious Pilkington Prize for excellence in teaching.

The prize recognises Alan's outstanding contribution to the IfM's flagship educational 'Robot Lab', which has become one of the defining features of the Manufacturing Engineering Tripos (MET) and one that students regularly cite as the highlight of the course.

Having worked tirelessly to optimise the learning experience of automation for manufacturing engineering students for the past 25 years, Alan has been described as an 'exemplary educator' by his colleagues.

Professor Tim Minshall, Dr John C Taylor professor of innovation, Head of the IfM and MET IIB Course Director, said: 'It is clear that Alan is an outstanding educator, who always puts the students' learning experience and well-being before his own. We cannot think of anyone more deserving of the Pilkington Prize as recognition of the past 25 years of extraordinary and exemplary teaching and outreach contributions.'

The Pilkington Prize awards were established in 1994 by Sir Alastair Pilkington to acknowledge excellence in teaching. Each year, 12 prizes are awarded to individuals who make a substantial contribution to the teaching programme of a department, faculty or the University as a whole.

On receiving the award in June 2021, Alan said: 'I was surprised and delighted to win the Pilkington Prize. The Robot Lab is a real enabler for helping our students go on into industry and I'm so pleased it's been recognised in this way.' The Robot Lab has come a long way since its first incarnation in 1995, thanks to Alan, who has led its development through multiple phases.

Today, it is a central hub for both teaching and research communities, providing a safe environment where students and researchers can use the latest industrial equipment to gain valuable practical skills, while at the same time being able to test and demonstrate new academic developments.

As well as helping to design, set up and oversee all the technical elements of the Robot Lab, Alan has long championed its role in the development of professional engineers and as a key opportunity for students to apply and reflect upon knowledge gained in traditional lectures.

Beyond the Robot Lab, Alan makes substantial contributions to the MET IIA course through his leadership in workshop inductions and CAD-CAM exercises; and supervises several industrial student projects each year.

Alan is a member of the Distributed Information and Automation Laboratory (DIAL) research group, providing expertise in the area of Automation and Auto-ID technologies. He was Co-founder of the Aero-ID Technologies programme, working with Boeing, Airbus, Embraer and the ATA to help support the adoption of ID Technologies in the aerospace sector. More recently, Alan has worked on Boeing research programmes developing resilient production operations and led initiatives to deploy research work back into Boeing factory sites in the Seattle area. Alan is actively involved in helping companies develop industrial automation strategies, continuously reflecting on these developments and ensuring that teaching activities meet these needs.

Professor Colm Durkan, the Department of Engineering's Deputy Head of the Department for Teaching, said: 'Alan has always gone down the route of doing what he thinks is educationally best rather than what is easiest. Last year in particular was no exception, where Alan completely modified the Robot Lab to ensure our students got the most out of it. Alan's entire career has been spent putting student education at the top of his agenda.'

Alan said: 'The prize reflects the real teamwork that goes into making the Robot Lab work and I'm really grateful to everyone who supports its activities and it's development over the years.'

To find out more about Alan and the Robot Lab, read the full article by scanning the QR code below:

FOOD-ALLERGY INCIDENTS ARE RISING. HOW CAN FOOD MANUFACTURING IMPROVE?

The growing prevalence of food allergies has moved to the top of the food-safety agenda, with prominent news coverage raising awareness of this worsening problem.

In the UK, admissions to hospital for allergic reactions to food increased from 1.23 to 4.04 per 100,000 people per year between 1998 and 2018. Among them, the largest increase of hospital admissions was children under 15 years old, jumping from 2.1 to 9.2 per 100,000 population per year.

There is no cure for food allergies and the only way to prevent allergic reactions is to avoid trigger allergens. This is why mandatory declaration of food allergies has been included in international and national regulations, requiring food manufacturers to provide full ingredient and food-allergen information on the product label.

But despite the health and legal importance of declaring allergens, the number of incidents continues to grow.

As part of recent research, we collected all the food-allergy alerts between 2016 and 2019 from the Food Standards Agency for England, Wales and Northern Ireland, and from Food Standards Scotland and National Archives websites.

Among the total 435 food-allergy alerts collected, almost all were down to production problems: mislabelling accounted for 54% of the total, incorrect packaging for 19%, food-allergen contamination for 14%, and a lack of English labelling (the allergens not mentioned in English on the label) for 8%. We found varying but similar errors in studies across Australia, the EU, Hong Kong, New Zealand and the US.

Unfortunately, the incentive to adopt good practice is generally low among food manufacturers: many are not willing to go beyond the minimal certification requirements, assess their food-safety culture or implement food-traceability technologies proactively. And cost pressures mean that quality control is suffering at a time when it is needed more than ever.

There are a number of initiatives that can help address these problems. Intelligent food-traceability technologies that use machine learning can support operational improvements. Better and tighter regulation can increase the incentives for manufacturers to invest proactively. And a better food-safety culture could help avoid errors where communication and coordination between operators has failed.

But these cannot work in isolation. For food manufacturers to improve, it is important to look at the incentives of all the operators involved, and how these incentives can reinforce each other.

Good leadership is an important place to start. Creating a clear vision of food-allergen management, with recognition for good practice, can help operators to develop shared values and collaborate more efficiently to avoid food-allergy incidents.

Small changes to the operational environment can have a big impact — for example, colour-coded labels on production machines could make it easier and quicker for operators to identify the production lines dedicated to a specific allergen profile.

A good understanding of food-allergen management can also prevent potential risks. If facilities are set to avoid the crossover of open production lines (such as conveyor belts), they can prevent food-allergen contamination from spillage and reduce the risk of contamination.

But without a good knowledge of best practice, operators will have difficulty mitigating the risks of food-allergen cross-contact and avoiding airborne cross-contamination. A survey in the Republic of Ireland has shown that only 13% of food operators could list the 14 allergens identified in the relevant EU regulation and 28% of these food operators did not receive any food-safety training in Ireland. More than 50% of the workers surveyed did not know that celery, peanuts, mustard, sulphites, sesame seeds, lupin and molluscs are food allergens.

Inconsistent food-allergen labelling regulations across countries have also created difficulties. There are eight food allergens that are mandatory to declare for international trade. In the US, there are also eight food allergens, yet they include wheat rather than different cereal sources of gluten like the UN's Food and Agriculture Organization and the EU. EU regulations themselves specify 14 food allergens that are mandatory to label.

The different labelling regulations for imported ingredients or materials may cause confusion to operators and result in undeclared food allergens. More consistent regulation or a better food-traceability system that eliminates confusion would assist manufacturers to manage allergens more effectively.

A food manufacturer's allergen management is also constrained by its suppliers. For example, when the ingredient suppliers fail to label all the food allergens or use a confusing label, it is difficult or impossible for the food manufacturer to declare all the allergens correctly.

A broader, incentive-based system can help to increase awareness of potential risks. When some common errors are unknown to a food manufacturer, it may make the same mistakes that others made before. Allowing food manufacturers to examine their practices against common errors can raise awareness of poor practices and encourage them to take actions to improve their performance before the outbreak of any food allergy.

It can also facilitate collaboration. A shareable framework for all relevant stakeholders can contribute to the sharing of best practice and the improvement food-allergen management along the supply chain.

To make progress across all these issues, technology can help. As manufacturers collect more operational data, this could be used to benchmark the performance of food-allergen management, and machine-learning algorithms could help to more efficiently tailor incentives for better performance.

This is different from the use of machine learning in conventional automation and food traceability technologies, where machine learning is used independently and aims to replace human beings. Instead, machine learning can be used as a prediction tool to provide information to operators, instead of making decisions for them.

Focusing on incentives for manufacturers to improve can also assist the design of more effective food-allergen policies and regulations. Existing regulatory systems rely heavily on on-site inspections, which are costly, and the information collected is limited. An incentive-based regulatory system could transform the existing regulatory systems into more efficient, intelligent, and lower-cost systems.

With the increasing prevalence of food allergies and the severity of food-allergy incidents around the world, improving food-allergen management in manufacturing has become more prominent than ever. An incentive-based approach built around advanced food-traceability technologies, more effective regulations and better food-safety culture could begin to answer this growing problem.

This article was first published in IfM Insights on 21 July 2021.

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OPEN INNOVATION: SOLVING IP CHALLENGES FOR SMEs

Dr Frank Tietze, Head of the Innovation and Intellectual Property Management (IIPM) Lab at the IfM, and co-author of a European Commission report looking at IP and Open Innovation (OI), explains how SMEs can use IP more strategically to gain competitive advantage.

As a hotbed of creativity, small- and medium sized enterprises (SMEs) drive growth by developing new technologies, products, services and software. Intellectual property (IP) can play a crucial role in helping to leverage the value of these innovations.

SMEs are very good at inventing and innovating. And as new solutions become more technologically complex, SMEs are more likely to collaborate in different forms of open innovation projects in efforts to drive long-term growth. Open innovation provides SMEs with key benefits such as access to new markets, new customers, and market knowledge; as well as access to complementary expertise and other technologies needed for innovation. Open innovation can also help SMEs to build their credibility and brand reputation.

But some studies (*Is intellectual property important for future manufacturing activities?* UK Government's Foresight Future of Manufacturing Project — Hall, B. H., 2013), suggest that only 6% to 8% of UK manufacturing firms own patents and other forms of IP rights, which leaves them potentially vulnerable to IP theft by partners or competitors, particularly when entering collaborative innovation processes.

This potentially poses a substantial threat to SMEs' competitiveness and survival. For SMEs to really gain from open innovation, understanding how to use and manage IP, particularly soft-IP (such as data, know-how, algorithms), is crucial in helping them to achieve their objectives. Put simply, those that understand how to use IP strategically have a greater probability of experiencing growth than those that do not.

While there is a lot of support around understanding IP essentials, there is very little available to help SMEs think about IP strategically, and to understand and manage it. So, what are the main challenges surrounding SMEs, open innovation, and IP? And what can be done to improve SMEs' IP capabilities?

The Top 4 challenges of managing IP in open innovation (according to SMEs)

A recent report prepared by the IfM and published by the European Commission, drew on evidence from SMEs (mainly from the EU) and uncovered four major reasons as to why they lack understanding and confidence in navigating and negotiating IP terms during open innovation collaboration.

1. Lack of strategic thinking around IP

A lot of SMEs we interviewed understood some 'IP essentials' but lacked in-house expertise/experience in managing IP strategically. This lack of a strategic understanding of IP creates challenges, for instance, when negotiating collaboration agreements, not only with other SMEs, but particularly with partners that are organisationally different, such as large firms and institutions.

These partners typically have established in-house IP capabilities. While there are options for SMEs to access external IP expertise, existing IP experts are mostly 'IP specialists' focused on particular types of IP, for example, patent or trademark attorneys/lawyers. A lack of strategic thinking may mean that negotiation leverage from IP is lost, and the SME may miss opportunities to derive value from their background-IP (IP that the different parties possess before a collaboration starts).

2. Difficulties in identifying and articulating background-IP

It's important that SMEs know and understand what background IP they possess before they begin collaborating. Ideally, they should undergo an audit or due diligence to understand what IP they already own. In the context of open innovation, not being clear about the comprehensive bundle of IP, including hard-IP and soft-IP needed for innovation, could undermine a collaborative project.

For example, data is a form of soft-IP that SMEs find particularly challenging to deal with. For instance, when developing digital solutions that require the integration of the developed digital component within the client's system and use of client data, SMEs can face challenges in determining the ownership of the foreground-IP (IP which is generated during a collaboration).

The study showed that SMEs find this particularly tricky. However, if they don't get this right, then the risk is that IP, which could and should have been background-IP, suddenly becomes subject to the foreground-IP sharing conditions negotiated in the open innovation agreement and it suddenly ends up being claimed by the collaboration partner. So, for SMEs, it's important for them to take stock of the background-IP they have and to understand what models exist and are preferred for sharing foreground-IP.

3. Lack of IP-specific negotiation skills

For SMEs, negotiating with partners who typically have established in-house IP expertise can be a daunting prospect. But it becomes particularly important to possess these negotiating skills when a SME's product is close to market and they are collaborating with a larger organisation, i.e., negotiations where there is a high commercial risk.

We spoke to SMEs who described weaknesses related to their lack of contract negotiation skills, inexperience with IP risk assessments and a lack of experience with dividing responsibilities amongst open innovation partners. Most importantly, SMEs said that they need IP negotiation skills to be able to arrive at favourable foreground-IP sharing terms which requires knowledge about possible foreground-IP sharing models, their advantages and disadvantages. Large firms appear to have a tendency of wanting to claim all IP, while SMEs advocate equal and fair IP sharing terms, while also wishing to restrict exploitation opportunities.

4. Organisational differences

SMEs tend to engage with other, larger firms, mainly because such collaborations offer competitive, commercial and market advantages. But differences in culture and mindset due to varying IP openness, a difference in approaches to contract formality, overall pace of progress, and risk tolerance all emerge as challenges when engaging in open innovation with such organisationally different partners.

What can be done to support SMEs in building strategic IP management capabilities?

There is a lot of IP support out there. However, much of it is very basic, and it's not focused on developing strategic thinking. Given this gap, in the short-term, SMEs can use simple tools such as cross-tables which can be used to allocate the IP they possess to their different products, technologies or services.

This can be a really useful exercise to do before they enter into collaborations. In the longer-term, to build the in-house strategic IP thinking needed for negotiating high commercial risk contracts for open innovation projects, we recommend SMEs access training programmes where they can learn and develop these skills.

For example, IfM Engage offers IP Strategy courses aimed at SMEs that helps them to build IP strategies and align their IP with business goals. Certain courses are aimed at C-level executives and do not require deep technical knowledge of IP, but rather seek to address IP as a strategic firm matter. IfM Engage also offers bespoke IP Strategy consulting to support SMEs with maximising the value of their innovation.

You can read the full report: 'Building stronger Intellectual Property strategy capabilities: Supporting SMEs to succeed with Open Innovation' by scanning the QR code below.

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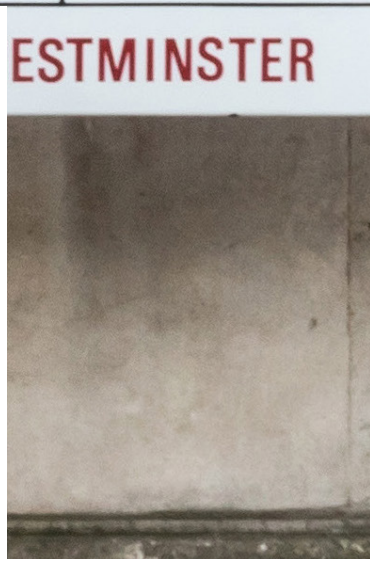

INITIATIVES TO BOOST STEM SKILLS IN THE UK CIVIL SERVICE MUST BE BIGGER AND BOLDER

Skills like problem-solving and quantitative analysis are growing in demand across the UK economy, including within the government itself.

While there has long been a view that Science, Technology, Engineering and Mathematics (STEM) skills are important to the knowledge economy, recently there has been a renewed focus on recruiting more people with STEM qualifications to work in the public sector. Sir Patrick Vallance, the UK Government Chief Scientific Adviser, is pushing to boost numbers of science and engineering graduates within the civil service during his tenure.

People with STEM skills are important to the civil service in a number of ways, including providing analysis, providing a deeper understanding of policy issues related to science and technology, offering different lenses for policy problems, and operating as translators between the worlds of policy and science.

However, our recent report on STEM professionals in the UK civil service reveals that the programmes designed to recruit for STEM skills are currently too small to be effective at the scale the UK requires.

Programmes such as the highly competitive Science and Engineering Fast Stream and the Government Office for Science's Graduate Internship offer excellent development for those who participate, and are important for their symbolic value, but they simply aren't large enough to boost numbers of science and engineering graduates within the civil service.

The Science and Engineering Fast Stream typically takes fewer than twenty candidates each year, while the Government Office for Science Graduate Internship has an annual intake closer to a dozen. However, on any given day there are as many as 1,000 jobs advertised online through the civil service portal. Comparing these annual intakes with the standard recruitment streams, it becomes clear that any strategy to boost numbers of STEM graduates within the civil service must be built into the standard recruitment procedures.

What's more, we found that it's difficult to estimate the current number of people working in STEM roles within the UK civil service, as this data is not systematically collected by the government. Most estimates put this value somewhere between 2.2% and 6.8%, though it may be as high as 9% to 13%. But our findings indicate that it is likely that there are fewer people with STEM degrees within the UK civil service than in other nations such as the United States and South Korea.

Strategies from other countries

To address this, we looked at international examples that could serve as models to the UK civil service to increase its attractiveness to STEM graduates.

Some countries such as Singapore use salary matching to market-competitive rates for STEM professionals. The UK government does not systematically undertake salary matching, though some newer measures are being introduced for small salary increases for specific technical roles, in the same way that London weighting increases salaries for those living within the capital.

Unlike the United States or South Korea, the UK has extremely limited potential to pay by performance within the civil service's current employment policies. In most departments, bonuses are awarded only in exceptional cases, and at less than 2% of salary. In contrast, in the US civil service, there is a special classification for research and development posts, and agencies pay these employees according to internally agreed performance targets. In Singapore, civil servants are paid bonuses which are partially linked to the nation's economic performance, and these bonuses can be up to 40% of the annual compensation.

While these approaches would be a drastic departure from the current UK model, there is merit in considering them for highly specialised or technical roles.

In Singapore, government scholarships sponsor study at local and international universities, under agreement that upon graduation, these individuals work for a fixed number of years in the civil service. These are highly regarded – 16 of the 20 permanent secretaries in post in 2009 had previously held these scholarships. While the UK does have a high-quality Fast Stream programme, the lower proportions of STEM graduates entering the civil service suggest that a similar scheme targeted at STEM graduates could be beneficial.

The UK government could also consider strategies for attracting higher-level skills. For example, in South Korea, there are mechanisms to appoint those with Master's or PhD qualifications into higher entry-level positions within the civil service than those with Bachelor's degrees. The lack of such differentiation in entry route and pay scale in the UK civil service has the effect of signalling that these additional qualifications are not valued.

If the UK government is serious about recruiting more people with STEM skills, the first step is developing a better understanding of the current make-up of the civil service. But beyond this, it is clear that the UK could benefit from looking at strategies from other countries to boost uptake, as revealed in our report.

For more details and references, please see the full report: *STEM professionals in the UK civil service: An international comparative study.* The report was prepared for and with the support of the Gatsby Foundation.

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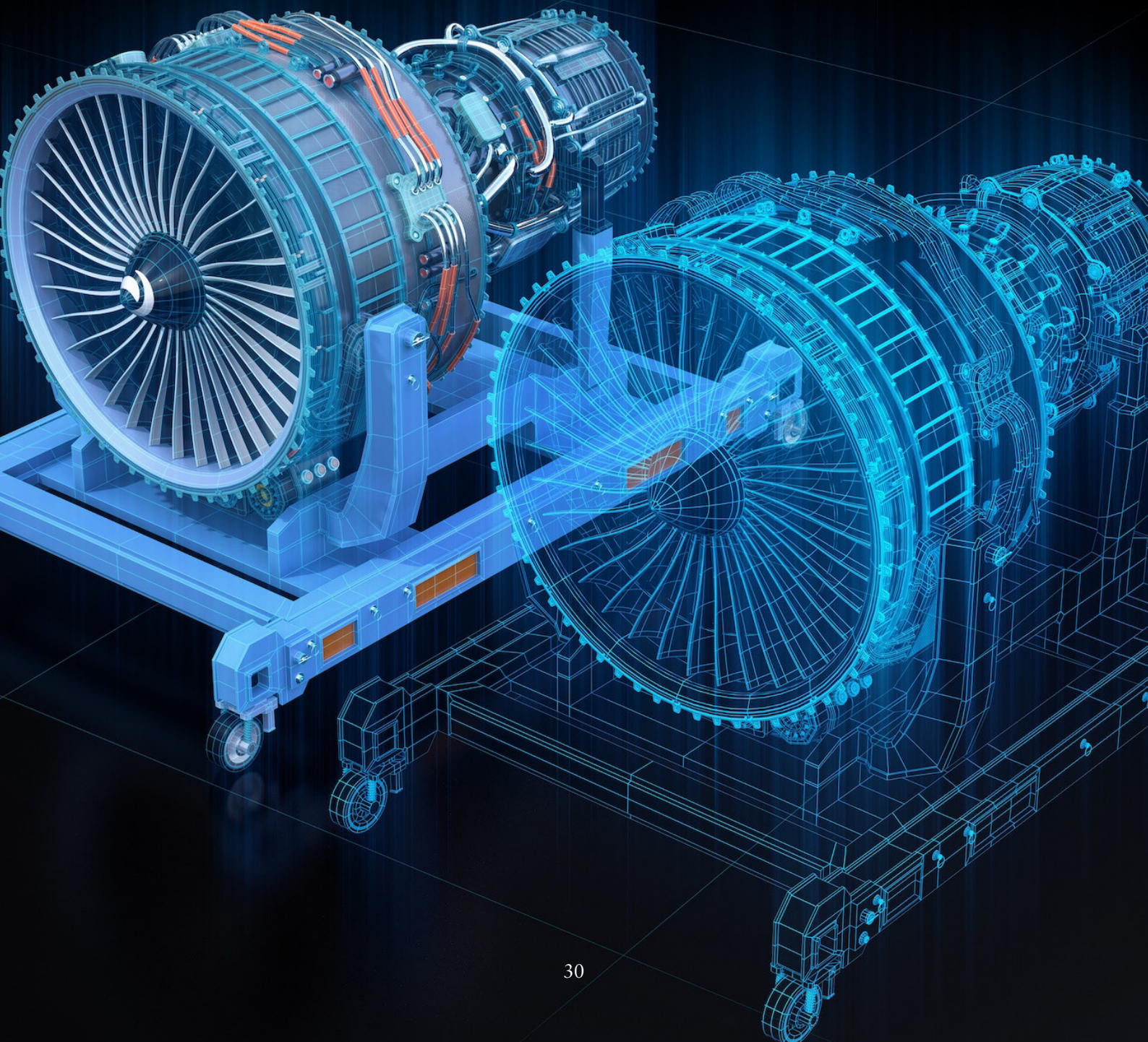
TO REMAIN COMPETITIVE, AEROSPACE COMPANIES NEED TO GET DIGITAL TWINS RIGHT



Digital twins are increasingly regarded as key components of digital transformation, particularly in asset-intensive sectors such as aerospace. As 'living' models that mirror the properties and actions of a physical entity, they have the potential to unlock new and innovative value propositions that can help companies achieve sustainable competitive advantage.

But while recognition of their value is growing, no one has yet emerged as an industry leader.

As part of our research, we spoke with over 50 industry experts from 13 different commercial aerospace manufacturers to understand how digital twins are being adopted and used within their companies. The results show significant variation in maturity levels across different dimensions, with no clear front-runners emerging.

For instance, only 15 per cent of companies have deployed their digital twins commercially. Almost 88 per cent of companies are using their digital twins' diagnostic and predictive capabilities, but only a small percentage of twins have moved beyond this to where they can automatically execute actions based off of the data.

One in six aerospace companies report that they are changing their business model as a result of digital twin implementation, but the main focus of activity is still at the process level, where the digital twin enables improvements to existing processes such as maintenance scheduling, rather than wholesale changes to their approach.

In the even more critical dimension of data accessibility, a quarter of the industry currently has no access to operational data of the physical products they sell, and half of the industry has only limited access, despite data access being critical to operating the digital twin.

Interestingly, we found that many of the leaders in each of these dimensions were different, showing that most companies are advancing only across a few of the 10 dimensions we identified: analytical capability, model update frequency, data collection frequency, modelling scope, decision implementation, life-cycle integration, digital twin individualisation, business models, operational data accessibility and commercial implementation.

Success factors and challenges

In our discussions, a clear consensus emerged as to the success factors needed for digital twin implementation: a shared vision of the objectives, frequent communication within and across departments and the right set of digital and data skills in the workforce. The importance of partnerships was also highlighted by almost all companies, reflecting both the need to collaborate with specialists to provide the best possible solutions and for gaining access to data.

The most critical barriers to implementation were seen as resistance to change within the company, an inability to develop a convincing business case and a lack of access to data.

This challenge of data accessibility exists both outside and within the company. For example, one department may gain access rights to external data but other departments are not covered by the contract agreement and hence cannot access it. This highlights the critical role of contractual agreements in being able to implement and exploit the digital twin to its full potential. You need to have access as a company to operational data and you must be able to share that data across departments.

But challenges go far beyond the technical. The lack of a data-driven culture is a major issue to which companies must pay particular attention. It is important to find a balance between more experienced employees who rely on intuition and younger, data-driven employees who lack field experience.

Solving these challenges and moving forward across the multiple dimensions of digital twin implementation is essential to competitiveness. Customers are increasingly looking to digital twin implementation as a point of differentiation between aerospace manufacturers, and it is likely that certain operational levels of digital twins will soon appear in regulation as well.

Digital twins are a multidisciplinary endeavour that crosses company boundaries. Therefore, they require cultural changes within the company and throughout its ecosystem, with a shift towards digital and analytical literacy, as well as data and information-sharing. Those companies that can truly leverage systems-thinking and nurture stakeholder relationships will be well positioned to harness the potential of digital-twin-enabled offerings.

Find out more in our full report, Digital twins in the aerospace sector: Maturity model, practices and opportunities.

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EIT FOOD ACCELERATOR NETWORK PROVIDES SHOWCASE AND SUPPORT TO GROWING AGRITECH AND FOODTECH VENTURES

The IfM is in the fourth year of running the Cambridge hub of the network, offering expert mentoring and helping agritech and foodtech start-ups across Europe to increase their chance of becoming commercially and sustainably successful.

The EIT Food Accelerator Network is a network of hubs across Europe which help agritech and foodtech start-ups to develop their technology and business, providing mentoring and linking them with major corporate and research partners.

Cambridge is the site of one of six hubs, with the IfM taking the lead. The programme draws on both the expertise from the institute and the wider network that helps new ventures connect with those that can help them.

'The great thing about the model we use is that it's not a universal, where they're all taught the same things,' says Ian Bamford, Commercial Director for the IfM's Centre for Industrial Sustainability, which runs the Cambridge hub.

'We use a process called the 'triple chasm model' to evaluate where they are in their journey and to help them to focus in on the areas where they may have weaknesses. The model tells you why your venture is different to the others, why one needs to do more on, for example, marketing and PR, while another needs to do more on the technology that underpins what they're doing. This helps companies focus on improving the things that are going to be really advantageous to their own journey.'

An important part of that model is the one-to-one relationships that can be formed with mentors.

'A mentor has a lot of experience so we can answer some simple questions,' says Gary Punter, a Visiting Fellow at the University of Cambridge who has provided mentoring for the past two years.

'A basic one is: Where do you add value? Many start-ups will talk excitedly about the technology they are developing, which is understandable, but to take the next step they need to think in terms of the value that they are bringing to the customer.

'Once you understand how the customer looks at your business, you start to understand where your niche is, how you set prices... all the things that define your value to the customer. Everything leads from there.'

For Punter, finding an ambitious, but realistic, path forward is the goal. 'It is interesting. You get some companies that are idealistic — because we are focused on sustainability — they are idealistic eco-warriors who have a grand idea and want to save the world. And that's not going to work,' he says.

'At the other end of the spectrum, you have people who are so hands-on and close to the coalface that they're not lifting their heads up, and they're working themselves into an early grave, and the business suffers there as well.

'If we're lucky, the ones that come through are in the middle. They've got the passion — as a mentor, I'm looking for people with passion and purpose. And then we try to help them put some shape to that. With passion, purpose and shape, you're well set up."

Mentoring takes place in conjunction with networking and matchmaking

opportunities throughout the year of the programme. The biggest of these is a showcase event at the end, which allows the new ventures to present their plans to potential investors, corporate partners and other companies who could help them find a route to market.

After four years of the programme, the benefits are beginning to show. A venture from the first cohort in 2019, Deepbranch, a company which uses CO2 captured from power stations and hydrogen to create sustainable animal feed, raised over £6.5 million last year, helped by contacts that they made through the Food Accelerator Network.

'In general, it was a really good experience,' said Pete Rowe, CEO of Deepbranch. 'Tapping into the local expert pool here [in Cambridge] was really useful. It was nice that [the team] went through the effort of bringing on board experts from different companies based on who was here.'

Last year's start-ups are hoping to build those valuable connections as well, with both investors and each other.

According to Bamford, the relationships built between ventures, who might be future partners, share technological insights, or just become friends within the industry, are an important part of the network as well.

'They've been a really dynamic group this year," says Bamford. "Each group — we've done three now — each group is very different. They have their own characteristics. This year, they've found it easier to engage remotely than last year's group, who were trying to do it for the first time. So they've been more comfortable in saying what they think. They've known how to interact effectively remotely. And they've been very engaged.'

While the network is geared towards generating progress for the start-ups, Punter says it is equally rewarding for the mentors.

'It's interesting to see the waves of innovation come through," he says. 'And it gives me a very good insight as to some of the talent that's coming through. That's really reassuring.

As someone towards the end of their career, it's great to see these entrepreneurs and creative people who are starting their careers.

'As mentors, we try to be kind and constructive. They're doing things we've never done. I have a lot of empathy for them, and I think they're quite courageous.'

You can learn more about the ventures from the Cambridge hub on our website.

This article was first published in IfM Insights on 2 December 2021.

LEADING ORGANISATIONS IDENTIFY PRIORITIES FOR A SUSTAINABLE MANUFACTURING FUTURE

The Sustainability Association, launched by the Institute for Manufacturing (IfM) in early 2021, held its first member meeting with manufacturers including Toyota, Airbus, Emerson Global, Modulair Group, Worthington Industries and others, joining together to tackle the core issues of implementing sustainable change. The meeting, held in November, was the first in a series of activities designed to help its members achieve sustainable transformation in their organisations.

Key issues including how to achieve carbon zero, how digital can support sustainability and how to achieve quick wins using existing technology and know-how have been identified by members as collective problems for the Association to address in order to tackle sustainability.

Using existing tools and cutting-edge research blended with virtual and in-person events with expert speakers and workshops, the Association will unpack these topics, providing its members with the right knowledge and expertise to start implementing meaningful changes straight away:

'For manufacturers, there is now a real opportunity to be proactive in recognising future challenges, taking decisive action, and making the most of the opportunities that will come from a global shift toward sustainability. It's a daunting task. But it's one manufacturers should – and need to - address as the sustainability imperative continues to grow,' says Professor Steve Evans, Director of Research in Industrial Sustainability, Institute for Manufacturing, University of Cambridge.

Sustainable manufacturing: from vision to action

At the meeting, directors and senior executives from a range of global technology, engineering, and pharmaceutical companies heard from leading experts (Professor Steve Evans and Dr Sheikh Ali, Siemens Factory of the Future) on how digital has a strong role to play in driving sustainable business and how these two areas of change are interlinked; and how the development of agile biorefineries can affect other forms of manufacturing (from Gary Punter Fellow, Institute for Manufacturing and Associate Professor Nik Watson University of Nottingham). An important part of the event – and Association membership – is the opportunity to create a strong community of businesses that are motivated towards achieving a more resilient and sustainable future:

'Hearing about areas of progress and innovation is always inspiring – even those that were not directly applicable to my company – and sparked a conversation with other attendees that helped to develop ideas and plans for driving sustainability,' says Association member Peter Lake, Director Operational Excellence, BTG Specialty Pharmaceuticals.

'Next year, I am looking forward to more inspiration from those leading in the sustainability arena, and in sharing and learning from other association members on how they are overcoming challenges and taking action to approach net zero.'

While Association members vary in size, Ian Bamford, Commercial Director Centre for Industrial Sustainability at the IfM, says that sustainability challenges are surprisingly consistent:

'What's extraordinary about sustainability for business is that although companies may differ in scale and the sector they operate in, the challenges they are facing are very similar. The Sustainability Association gives members the chance to meet with like-minded peers from different industries who are trying to solve similar problems.'

For member Patricia Lorton, Director of Sustainability, Worthington Industries, the Association will help focus attention on key areas needed to bring about transformation:

'Bringing about change sustainably is complex so it was good to share common challenges with like-minded peers. I'm looking forward to next year's programme, which will help us understand which areas should be central and how can I prioritise actions for our business.'

Focus areas for 2022: Seven themes to support sustainable manufacturing

Looking ahead, the newly established Association will be shaped and driven by its members so that future activities can focus on areas where members feel most value can be added.

'We want to bring interesting, useful ideas and exciting thought leadership to our events and provide members with the right kind of content they need to move forward. We've listened to the challenges and aspirations of our members through workshops and have established themes that will drive content and discussions as we move into 2022 and beyond,' says Ian.

Members had the chance to vote on the themes during the recent meeting, and those selected are:

Theme 1: Effective sustainability measurement, reporting and prioritisation
Theme 2: Quickly achieving improvements in resource and energy efficiency
Theme 3: The emerging role of digital activity to transform the sustainability journey
Theme 4: What will it require for manufacturers to achieve carbon zero?
Theme 5: Introducing radical manufacturing approaches to the Sustainability Association
Theme 6: Creating sustainable industrial architectures and system-wide changes
Theme 7: How to create an effective business case for sustainable transformation

To help members to connect with each theme, the Association has a series of engagement and research activities planned for the coming year.

To find out more about the Sustainability Association, including the programme of activity for 2022, scan the QR code below.

HOW STRATEGIC ROADMAPPING CAN SIGNPOST THE ROUTE TO THE FUTURE

Roadmapping is a powerful approach that can help organisations to effectively plan and communicate their strategy. Dr Imoh Ilevbare, Principal Solution Development Specialist at IfM Engage, explains why he loves helping organisations to create their own roadmaps, how its visual approach helps organisations to design and communicate their strategy more effectively, and reveals some of the best and most interesting examples he has seen.

A strategic roadmap is a structured forward-looking diagram that sets out an integrated view of the way forward for an organisation, sector or other system. A roadmap is not a static forecast, but rather a device to support strategic navigation, updated periodically as events unfold and new knowledge is gained.

Although the most common visual format looks similar to project and programme plans, roadmaps have greater scope and a longer time horizon, providing context and direction for strategic decisions, plans and budgets. Dr Imoh Ilevbare provides consulting on roadmapping through IfM Engage and is one of the course leads for the Product-Technology Roadmapping course for Cambridge Advance Online.

The first step on the roadmapping journey

I first came across roadmapping in 2007. I trained as a mechanical engineer, where I always thought about fixing and making things. That's my primary training. But I always had an interest in the management and strategic aspect of manufacturing. I was also quite interested in how to apply something like roadmapping to difficult, complex and uncertain situations.

In fact, my first reaction was to apply roadmapping to technology transfer into developing economies, which is something that a few people since then have tried to do.

Roadmapping is very much about how you can make sense of an uncertain situation, so it was appropriate to apply it to developing economies where there can be less structure to industry and innovation systems — there is usually a bit more uncertainty, coupled with other things, such as political issues, which add ambiguity. How can you figure all of that out and still be able to do something good, such as being able to transfer technology from one part of the world to another? That question is what drew me to roadmapping.

In fact, I've discovered that some people consider roadmapping a risk-management tool, and that makes sense, though I might call it more of an uncertainty management tool. It helps you make sense of such situations. It doesn't do that just by itself, it's about the process that helps you to structure your mindset and helps you to see where gaps or interlinks are. Then you can make better decisions based on the picture in front of you.

A visual approach to strategy

Roadmapping is a very visual approach to strategy, and this can help an organisation in two ways. It helps in the actual creation of the strategy itself, but also, importantly, it helps in the communication of the strategy. The roadmap itself is visual, of course, but the process we follow in creating it is also visual, in that we use charts and templates.

People have to interact with these as individuals and as a collective to contribute their thinking. This allows people to externalise the information in their heads — it also helps other people to pick up on these, build even more ideas and improve the thinking. In

addition, when you map things out, you can see patterns more easily, helping to identify where there is a lack of information or knowledge.

You can then decide to either focus on that blank space and figure it out, or you can ignore it — but you're doing so consciously and with reason. So, the visual nature of the roadmapping process aids communication and helps people to exchange information and to learn from one another. And, of course, a good roadmap, laid out on the page, helps others, not directly involved in its creation, to understand the developed strategy as well.

Roadmapping misconceptions

Many assume that it will be difficult and complex, but it doesn't have to be. You might see some roadmaps that can seem very sophisticated, but they don't have to be complicated, especially when you are starting out in your application of roadmapping. It is usually good to start simple or small, and then as you build your roadmapping capability you can increase the level of sophistication. You can create some nice, clean roadmaps just based on a bit of solid information and analysis. And when we go through our step-by-step process, and the logic is clean and clear, people get it.

We talk about the 'why, what, how' and use those principles through the process. Of course, it takes a bit of practice to become proficient and apply those principles in different contexts, but it's something that most people can pick up and run with. A finished roadmap may look quite complex and full of different elements, but the actual process for developing it would be quite logical and, to be honest, if you strip it down, it's quite simple.

It's all about timing

When people hear 'roadmaps', the first thing that comes to mind is usually something like Google Maps, a platform that helps you move from point A to point B, over space or distance. They wouldn't be completely wrong to think that. But what we are creating here is not that — it is a strategic roadmap over time, not distance. So time is an essential element of our roadmaps. Every element of the roadmap needs to have a 'when' associated with it.

All the key strategic questions (i.e. why, what, how) are linked, but 'when' is a fundamental part of the roadmap. If you are asking 'why?', it needs to be with respect to time: Why is it important to act now? Why would it be important to act with respect to the future? And so on. Without that, you don't really have a roadmap — and even with the 'why, what, how', you'll only get a static strategy map. You would be less able to tell the story of your journey, and easily see the next steps you have to take to get where you want to be.

Why is roadmapping useful in manufacturing?

The earliest incarnations of this concept were technology roadmaps, which tried to figure out what technological development would be required now, and in the next few years, to be able to achieve certain innovations in the future. In technology development, there are so many different variables, so you needed something that could break down the complexity of the system into key dimensions. If you look at the entire value chain of manufacturing, you see a similar complex system — one that is often based on technology.

Think about the initial phases of ideation, the so-called 'fuzzy front end', where there is a lot of uncertainty. What sort of technology should we invest in? What sort of products and services we should try to develop? You need some strategic perspective. Because you start the process of developing your concept, and depending on the industry, it might be months, years or decades down the line before whatever you are developing makes it to market. If you think about manufacturing as being essentially based on engineering, and based on technology, it becomes clear why these concepts translate.

The best roadmap

I wasn't involved but I provided advice on a roadmap by Richard Pearson created for a nuclear fusion reactor. I like how it is laid out — it looks like a really sophisticated roadmap, but it is easy to follow. And it shows how you can lay out all the things you need to get to what you are trying to deliver — the technology development that is required, the physics, the engineering, the other sorts of fundamental science that might be required, and how rich a picture that can be while still being simple. Another one that I really like, and we use it a lot as an example, is the Motorola Car Radio Roadmap created in the 1980s (Willyard & McClees, 1987). It's clean, very easy to understand, and shows some of the fundamentals of what roadmaps should be. If I were to choose one of mine, among those that are publicly available, I would refer to the roadmap for the National Physical Laboratory (NPL). It may not be the best of mine in terms of aesthetics, but it has been one of the most effective. There were about 50 organisations involved and about 100 individuals, so it was a big deal, but it has been taken seriously by the Department for Business, Energy and Industrial Strategy (BEIS). It has informed a programme of work and ended up as one of their highlights of the year in 2017. I am proud of that one.

Unlikely roadmaps

Sometimes you see roadmaps with peculiar visuals that you can't understand until you read the accompanying document. If you have that, it doesn't necessarily make it a bad or an odd roadmap, but it probably could have been done better. I've come across some of those.

However, some are peculiar in a good way, especially ones that use metaphors or are more pictorial. There is one on high-energy particle physics looking at the particles that have been shown to exist through theoretical physics but have not yet been observed. This roadmap tracks what you would need to deliver on the proof that those particles exist. It uses the metaphor of mountains, and each mountain peak is a different particle, with spotlights showing the tops of those mountains.

Each of those spotlights is a different type of technology or resource that you would need to actually observe the particles and provide the proof that they exist. That's an interesting roadmap, and it's a powerful one, even though it's very different from some of the others.

This article was originally published in the April/May 2022 issue of
THE MANUFACTURER

DON'T FEAR THE ROBOTS: HOW DEVELOPING COUNTRIES CAN PREPARE FOR INDUSTRY 4.0 AND SAFEGUARD JOBS

For manufacturing in developing countries, the impact of digital technologies is likely to be slower and less disruptive than feared. But policy action is needed to avoid deepening existing inequalities.

The potential of digital technologies to automate routine tasks and replace human labour can sometimes seem like an existential threat to manufacturing in developing countries, with some reports identifying up to 85% of jobs as being at risk.

Such predictions tend to be based on technical feasibility. However, the automation of jobs also depends on economic and institutional feasibility, and these factors can outweigh the technical aspects.

Digital technologies are undeniably transforming production systems, trade networks and labour relations; however, the pace of these changes is likely to be slower and less disruptive than many studies have predicted.

Lower labour costs, younger populations, limited infrastructure and skills shortages make a weak economic case for embarking on large investments in automation in developing countries. For example, the World Bank has estimated that, adjusting for lower wages and slower technology adoption, the share of jobs at risk of automation is reduced by half in countries such as Cambodia and Ethiopia, and by one-third in countries such as Bolivia, Nigeria and Thailand.

And automation can be challenging even in developed countries where firms may find more advanced infrastructure and skills – witness Adidas, which over the past two years has decided to stop operations in the 'speedfactories' that they opened in Germany and the US just a couple of years previous.

This, however, does not mean that least developed countries and developing countries cannot benefit from new and emerging technologies.

Technological change is happening, both in developed and developing countries, and this trend has been further accelerated by the COVID-19 pandemic. A survey conducted among 3,450 executives across developed and developing countries found that 59% of organisations had accelerated their digital transformation as a result of the pandemic, while 66% reported they had been able to complete digital initiatives that previously encountered resistance. Our work in Cambodia, Indonesia and with the Commonwealth Secretariat has focused on exploring opportunities that digital technologies can offer to developing countries. These range from the adoption of low-cost, off-the-shelf technology solutions to improve firms' efficiency and productivity to the delivery of 'smart' services and frugal innovations to adapt open source technologies to specific contexts and needs.

Industry 4.0: Beyond the robot hype

Digital technologies enable automation, and this capability has become central in the debate about massive job displacement. However, digital technologies involve more than robots, and their capabilities go far beyond automation.

From the different applications of digital technologies, our work has focused on those concerned with industrial manufacturing. These applications, commonly referred to as Industry 4.0, concern the integration of the cyber world of information and communication technology, like software and wireless communication,

with the physical world of operation technology, like machines and their human operators.

This cyber–physical integration enables automation, but also other useful capabilities, such as decentralisation, virtualisation, real-time response and flexibility. For example, in an ongoing project in Cambodia in collaboration with the United Nations Development Programme (UNDP), we have identified opportunities for improving business efficiency and productivity by leveraging production management systems, both in garment and agro-processing firms. These technological solutions are enabling firms to gather and analyse real-time data on the availability, performance and quality of production lines.

While robots are increasingly being used, there are other and more affordable Industry 4.0 technologies that show higher rates of adoption, and have the potential to create more immediate improvements in company performance. These include cloud computing, the Internet of Things and big data analytics.

During the COVID-19 outbreak, these technologies have gained even more importance. A study conducted by the IBM Institute for Business Value across 20 countries and 22 industries found that, during the pandemic, cloud computing, artificial intelligence and data analytics were larger drivers of business revenue than robotics.

Skills for an inclusive industrial digitalisation

As part of our work in collaboration with the Asian Development Bank (ADB), we conducted a review of international studies which revealed a great deal of variation in predictions of the impact of automation on jobs. Figures go from the creation of over 100 million jobs to the loss of over 200 million. While there may be a lack of consensus on the overall net impact on jobs of the adoption of digital technologies, most of these studies agree that there will be winners and losers in this so-called Fourth Industrial Revolution.

The production and trade of new products will create new job opportunities for those who have, or acquire, the relevant skills. Better equipped firms and individuals are already reaping the benefits of Industry 4.0 technologies, and deepening market concentration and social inequality. The COVID-19 pandemic has further exposed these inequalities, affecting certain population groups disproportionally, including the self-employed, women and working people on both extremes of the age curve.

Drivers of competitiveness are also changing. As factors such as environmental sustainability, social responsibility, and supply chain transparency and agility are increasingly important in international markets, the adoption of digital technologies is becoming a prerequisite to participate in global value chains.

Given the rapid pace of technological change, it is imperative that governments work in collaboration with industry, employees, and education and training institutions to ensure that firms and individuals acquire the capabilities needed to participate in the opportunities created by Industry 4.0.

Governments and industry will need to address safety risks emerging from new forms of human–machine interaction and exposure to new materials. However, digital technologies can also be leveraged to improve occupational ergonomics and overall employee safety, reducing the need for humans to do physically hard or dangerous work.

Although uncertainty exists in relation to how new technologies will affect jobs in the future, a clear trend is already being seen: skills shortages. According to *The Future of Jobs Report 2020*, skills shortages represent the main barrier to the adoption of new technologies. This is a pattern that we have also observed across our projects in both developed and developing countries.

Throughout our work, including consultations with firms and the review of recent trends, we have identified that abilities demanded by firms adopting Industry 4.0 include:

- Digital skills (such as cloud computing, computer networking, cyber-security, data analytics, IT infrastructure management, information management and software development)
- Managerial skills (such as decision-making, leadership, technology trend monitoring, project management and strategic thinking)
- Production skills (such as lean manufacturing, operations management, quality management and supply chain management)
- Innovation skills (such as adaptability, creativity, critical thinking, and engineering and design)
- Other soft skills (such as problem-solving, mindsets for independent and lifelong learning, and communication)

Policy options

Although the massive job displacements predicted by some studies are unlikely to happen, at least not in the near future, there is increasing evidence that the digital divide is deepening economic and social inequalities. Without the right policies in place, developing countries risk being left further behind in the digital transformation journey. Throughout our work, we have identified three key areas of policy action that can help countries reap the benefits of Industry 4.0 technologies: (i) placing people at the centre of the digital transformation, (ii) easing access to technology, and (iii) improving the institutional framework.

People

Placing people at the centre of the digital transformation involves implementing policies to mitigate negative impacts, including:

- Establishing industry–employee–government–university dialogues.
- Developing programmes for workforce reskilling and upskilling.
- Adopting lifelong learning approaches in vocational training and education.
- Delivering safety-net schemes for those losing their jobs.
- Adopting gender-sensitive approaches in policy design and delivery.
- Ensuring compliance with labour regulations.
- Adapting regulations and ensuring compliance with international standards to address new safety and health hazards.

Technology

Although these technologies are becoming cheaper and easier to adopt, a lack of information on their availability, benefits and risks can hinder technology adoption. SMEs may also need additional financial and technical support. Activities that can contribute to ease access to Industry 4.0 technologies include:

- Raising awareness of the benefits of Industry 4.0 technologies and cyber-security threats.
- Financing of technology adoption, adaptation and development.
- Developing business advisory services and technology-transfer centres to build firms' capabilities and support technology adoption.

Institutions

Although skills are one of the main barriers to technology adoption, governments also need to continue their efforts to improve the institutional framework, and to further develop their national innovation systems. Key actions include:

- Updating regulation and ensuring enforcement.
- Creating governance structures for the coordination of national digital policies.
- Improving the business environment (e.g. cutting red tape).
- Investing further in physical and digital infrastructure.

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