ENGINEERS IRELAND

Industry 4.0 – Manufacturing Industry in Ireland

Engineers Ireland policy statement

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Overview

Digitalisation is becoming pervasive in our daily lives and is driving a level of connectivity never before seen in society. The internet, associated connectivity and social media are radically changing how we, as a society, interact. Increasingly high levels of goods and services are purchased online using mobile technologies.

These same connectivity tools are now providing the backbone, together with advances in production machinery, process control (including the upskilling/re-skilling of employees) and materials technologies, of a revolution in global manufacturing generally referred to as Industry 4.0 – the 4th Industrial Revolution.

Whilst the effect of Industry 4.0 can be seen in all aspects of an organisation, this policy statement will be limited to considering the implications for manufacturing, i.e. producing. The policy statement will consider the current state of play and Ireland's ability to maximise the benefits of implementing Industry 4.0 techniques and technologies as appropriate.

National action is now needed, as a matter of urgency, to prepare Ireland for Industry 4.0 and ensure that our manufacturing base survives and flourishes in the future providing high-value employment and growing exports.

The statement outlines our recommended actions for the Strategy in four key areas. A selection of these actions is summarised below.

A Awareness - building and collaboration

- Showcase digitalisation in manufacturing and generate media interest
- Join the international alliance 'Platform Industrie 4.0'
- Develop a national Industry 4.0 portal to provide information targeting SMEs

B Education and re-skilling employees

- Develop education programmes on new areas in digitalisation
- Include data capture, analytics and critical evaluation in degree programmes
- Establish a structured Industry 4.0 SkillNet

C Measures to support RD&I spend and capital investment required by manufacturing companies

- Ensure competitive financial terms for capital investment relating to Industry 4.0 are available to industry in Ireland
- Ensure industry in Ireland is deriving maximum value from European programmes
- Consider financial supports as applied in other Member States

D Co-ordination and collaboration of activities across the national response

- Increase collaboration between research performing organisations
- Agree mechanisms of collaboration between EI, IDA, SFI and industry consortia
- Manage the co-ordination of national efforts through the Technology Centres

1. Introduction

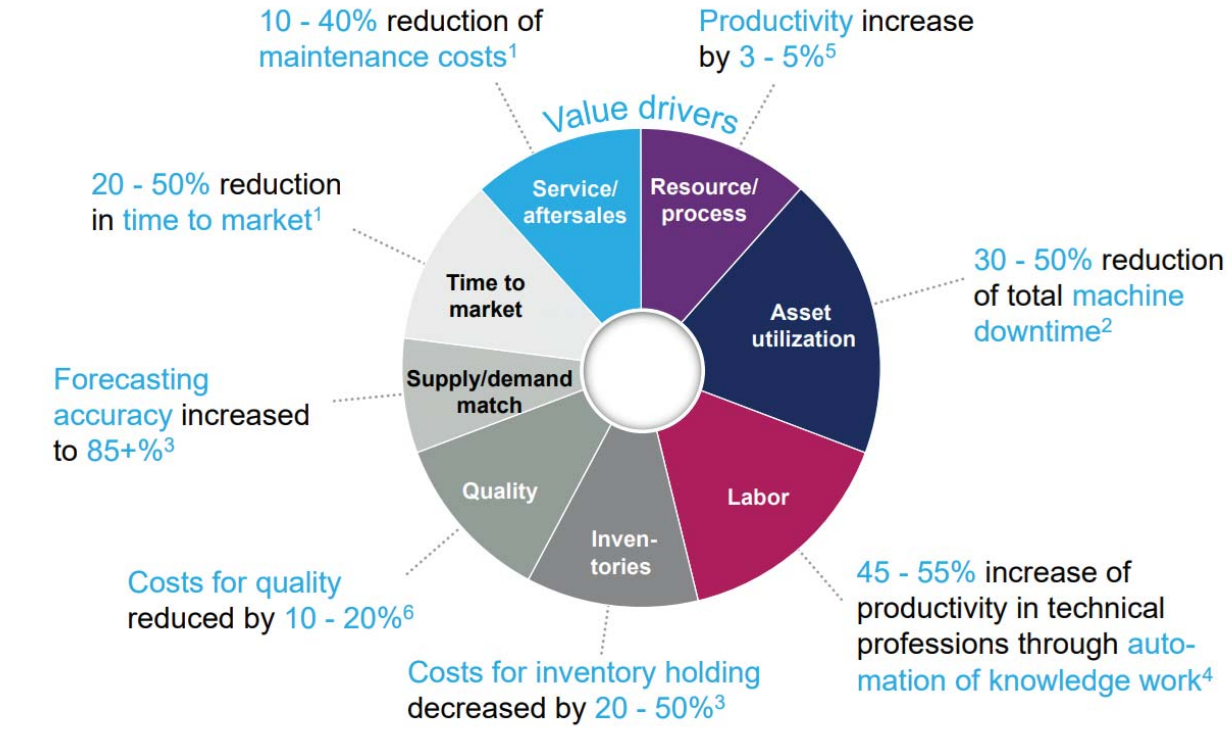
Digitalisation is becoming pervasive in our daily lives and is driving a level of connectivity never before seen in society. The internet, associated connectivity and social media are radically changing how we, as a society, interact. Increasingly high levels of goods and services are purchased online using mobile technologies.

We increasingly expect "new, individual, high-quality and nevertheless inexpensive products within shorter and shorter periods of time. At the same time goods have to be manufactured from increasingly scarce resources, as sustainably as possible".[1]

Developments within the entertainment industry are moving rapidly to implement Virtual Reality solutions, with associated software and hardware developments, to enhance the user experience.

These same connectivity and entertainment tools are now providing the backbone, together with advances in production machinery, process control (including the upskilling/re-skilling of employees) and materials technologies, of a revolution in global manufacturing generally referred to as Industry 4.0 – the 4th Industrial Revolution.

A recent report by McKinsey highlighted the advantages, anticipated by manufacturing companies, that will result from implementing elements of the Industry 4.0 toolkit (see Fig. 1 below).



1 Cf. McKinsey Global Institute: Big data: The next frontier for innovation, competition, and productivity 2 McKinsey analysis
3 McKinsey analysis 4 Cf. McKinsey Global Institute: Disruptive Technologies 5 See, for example, ABB case study
6 Cf. T. Bauernhansl, M. ten Hompel, B. Vogel-Heuser (Hrsg.): Industrie 4.0 in Produktion/Automatisierung/Logistik (2014)

SOURCE: McKinsey

Figure 1 - Anticipated Value Drivers from Digital Manufacturing Technology Implementations (Source: McKinsey & Company[2])

Whilst the effect of Industry 4.0 can be seen in all aspects of an organisation, this policy statement will be limited to considering the implications for manufacturing, i.e. producing. The policy statement will consider the current state of play and Ireland's ability to maximise the benefits of implementing Industry 4.0 techniques and technologies as appropriate.

Industry 4.0 will affect organisations in different ways and to varying degrees, some potentially not at all, but it is critical that company responses are aligned with organisational strategies – **Industry 4.0 is not to be seen as a stand-alone activity and an end in itself.**

National action is now needed, as a matter of urgency, to prepare Ireland for Industry 4.0 and ensure that our manufacturing base survives and flourishes in the future providing high-value employment and growing exports.

2. Manufacturing: Current state of play

This section outlines, at a high level, our understanding of Industry 4.0 and its relevance to Ireland.

How important is manufacturing to the Irish economy?

Manufacturing is a key industrial activity for Ireland employing 11.2% of the total workforce in 2016 and contributing almost 20% to national GDP. Further, manufacturing related value added is growing at 5.5% year-on-year.[3] A recent Ibec publication reported that there are 4,000 manufacturing related enterprises in Ireland of which 60% are indigenous companies.[4] The sector has a strong export focus with 71% of manufacturing entities exporting product to global markets.

Industry 4.0 - what does it mean for Ireland?

Industry 4.0, the overarching name given to the next disruptive industrial revolution, will have a profound impact on manufacturing industry in Ireland. 'Profound' because all aspects of manufacturing organisations will be affected. As Industry 4.0 continues to be rolled out and implemented, suppliers will become fully integrated into global supply chains of their customers (digitalisation), new production technologies (Additive Manufacturing, Ro- and Co-botics, Virtual, Augmented and Mixed Reality) will become commonly used and manufacturing processes will benefit from application of digital technologies.

In turn, this will lead to demands to **re-train and up-skill employees** in order to secure and grow Ireland's manufacturing base by creating greater value-added services.

Artificial Intelligence (Data Analytics and Deep Learning, Automated Processing, etc.) will bring new understandings to organisations and radically change their business models, for example, transforming manufacturing enterprises from product-oriented organisations to service based enterprises.[5,6]

The key enabler for the digital transformation of manufacturing is the Industrial Internet of Things (IIoT). IIoT connects the traditional analogue based automation infrastructure to the digital world, thus delivering a new level of monitoring and control. It consists of a new suite of intelligent sensors, machine to machine communication – cyberphysical systems, a new generation of manufacturing systems to support modular manufacturing, real time communication networks and data analytics. The application of IIoT results in Smart Supply Chains, Smart Factories, and Smart Products delivering new business models and opportunities. Realising the full potential of IIoT will demand reliable and secure connectivity (5G, wifi, etc) across the country.

Case Study 1 Industrial Internet of Things (IIot), Dairymaster

Dairymaster[7], based in Causeway, Tralee, Co. Kerry, has developed an innovative IoT based system to monitor cattle. Amongst the various technologies developed by Dairymaster is a product "MooMonitor+" which integrates technologies used within IOT systems.

The MooMonitor+ system uses the same technology as contactless payment to assign tags to cows. Each cow is fitted with a collar containing a Near Field Communication (NFC) Device equipped with a unique serial number thus allowing identification of each individual cow. This is a "wearable" technology using sensors to monitor the physical activity and condition of the cow. The system then links to a Cloud server system, which is an internet technology, which processes and stores the information from each cow.

The system gives information available on a 24hr basis, providing information on each cow concerning resting time, activity, feeding and rumination (all of which reflects animal health). Data from each cow is combined into big data, which can then be analysed to provide overall information for the farmer, allowing them to monitor production and health (allowing early intervention, reduced antibiotic usage, "heat" activity, monitoring for artificial insemination).

The system allows the farmer to improve the management of a herd by providing up to date information through accessible technology i.e. smart phone.

Dairymaster have developed innovative products for milking, feeding, cooling which are sold worldwide and have requirements for people in many areas of technology, Software Engineers, IT Support, Process/Production Engineers, User Interface Developers, Electronic Design, Mobile App Developers as well as Vision and Robotics Engineers.

In addition to the above, Sustainable Manufacturing underpinned by the efficiencies enabled by Industry 4.0 is a pillar of the European Commission's Green Economy policies.[8] Other reports which highlight the potential in the area of sustainable manufacturing, include the World Economic Forum report 'Driving the Sustainability of Production Systems with Fourth Industrial Revolution Innovation'.[9]

These developments will offer significant opportunities for the manufacturing sector in Ireland, including, the development of new product and service offers (supported by our research performing organisations (RPOs)), increased organisational efficiencies, new business models, increased profitability and export led growth.

But Industry 4.0 should be a cause of concern to policy makers both in Ireland and on mainland Europe.

A recent World Bank publication[10] warned of the effects on society resulting from the slowing pace of global economic growth, in particular the slowdown in trade, in parts and components and the trend of re-shoring traditionally labour-intensive activities – the latter being enabled through cost savings and flexibility realised through implementing new manufacturing technologies. Added to the foregoing, protectionist sentiments are increasing across a number of countries that have a national focus on manufacturing. Of direct relevance to Ireland, the European Commission report 'Redefining Industry'[11] highlighted that Ireland is one of the countries that is highly vulnerable to the effects of 'Made in China 2025'.

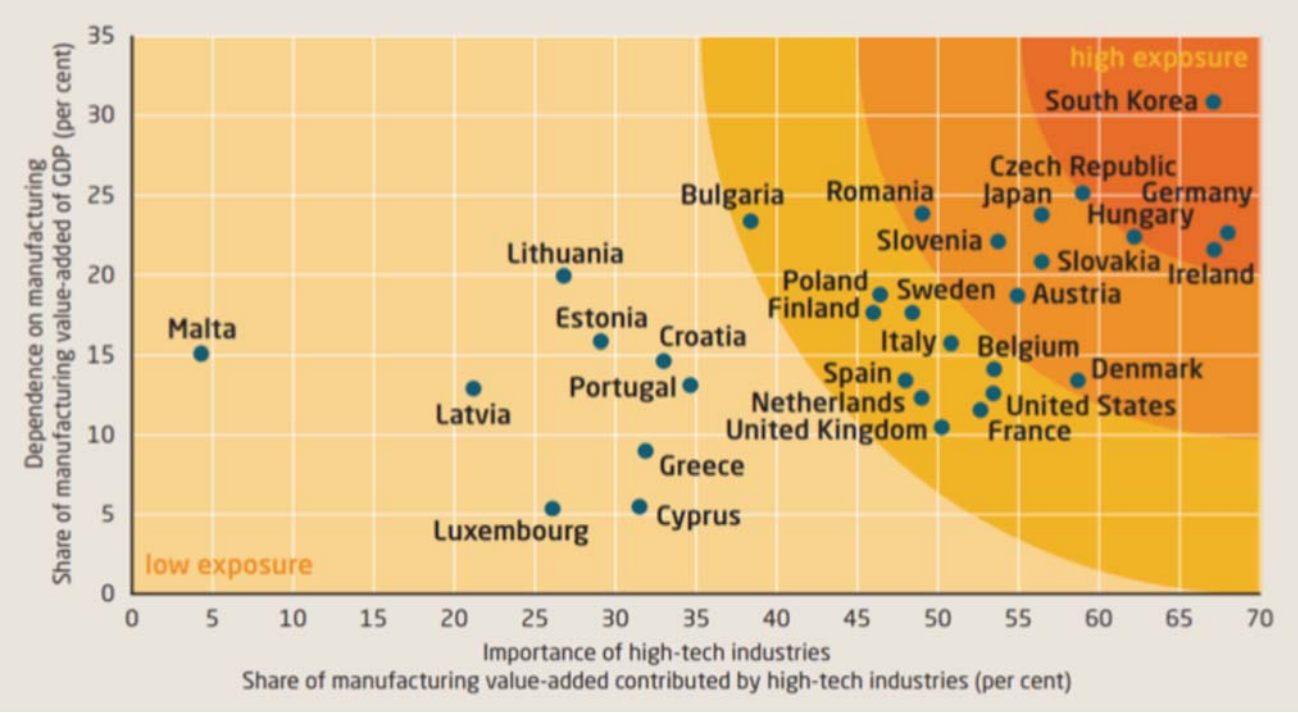


Figure 2 - Vulnerability of select industrial countries to Made in China 2025
(Source: Mercator Institute for China Studies[12])

More worrying, the World Economic Forum 'Readiness for the Future of Production Report 2018'[13] listed Ireland in the top ten nations globally under 'Structure of Production', complexity and scale of

a country's current production base. However, Ireland drops to 15th place when 'Drivers of Production', the key enablers that position a country to capitalise on emerging production technologies, are measured.

The potential impact of Industry 4.0 was highlighted in a recent report commissioned by the Bundesverband der Deutsche Industrie (BDI) and prepared by Roland Berger highlighted the economic impact of not implementing Industry 4.0 in Europe: "If Europe fails to turn the digital transformation to its own advantage, the potential losses for the EU-17 countries add up to 605 billion euros by 2025 – equivalent to the loss of well over 10 percent of the continent's industrial base. This would push the EU's stated aim of increasing manufacturing's share of European GDP to 20 percent by 2020 [...] out of reach." On a more positive note," for Germany alone, the positive scenario would add extra potential value totalling 425 billion euros by 2025. The corresponding figure for European industry as a whole would be 1.25 trillion euros over the next ten years." [13]

What are the key activities for Ireland?

Industry 4.0 should not be seen as an end in itself but rather as a tool to support an organisation's strategic objectives – growth and increased profitability.

There is a however, a lack of strategic understanding, particularly among SMEs, of the implications of Industry 4.0 on their organisations. A survey by Siemens found that less than one third of companies have a digitalisation strategy.[14]

According to the old Seneca saying "If one does not know to which port one is sailing, no wind is favourable". It is important to define the improvement you want to achieve before selecting the relevant digital tools and technologies needed to realise the organisation's strategic objectives. Hence there is an imperative for strategic awareness in companies to be enhanced in order to use and apply digital technologies in an efficient way. Individual companies must determine for themselves how best to address their strategic goals by taking the initiative to pilot a system or adopting a system in response to market pressures – maintaining competitiveness or responding to the needs of their customers as part of a global supply chain.

For other organisations implementing a comprehensive lean approach will be sufficient but many will have to implement aspects of Industry 4.0 to varying degrees.

In the near term, the developments most relevant to Ireland will include:

- **Additive Manufacturing (AM)**
  AM, the process of building 3D structures, using a variety of materials, has been available for about 30 years but recent technology developments are making its application more common. AM technologies are dramatically disrupting conventional product design methods and supply chain networks. The ability of AM to produce optimised designs not manufacturable by any previous technology is having significant impact across many industrial sectors. With

production being capable at any location via AM by secure file transfer, higher value add jobs will be created in the areas of product design for AM, new AM materials and methods, integration of AM into the manufacturing environment, including networking and optimised work flow as well as AM production.

Ireland's Focus on activities relating to AM should be:

- Development of applications, design and use, relevant to industry in Ireland
- Workpiece finishing processes
- Materials development (including functional materials)
- Smart process control and process feedback
- The wider integration of AM into supply chains
- An increased training of staff at all levels in their use and application

- **Cobotics and Robotics**

  The role of Robotics in industry is changing. Robots supported by modern compute power, internal and external sensor systems and utilising advanced communication protocols are becoming increasingly capable of sensing and adapting to changing environments. This is opening new application areas and reducing the painstaking development of models and the stringent reliance on static environments. Collaborative Robotics (Cobotics) is an extension of this trend, where the adaptation is centred on a human operator. These systems are designed to work in partnership with humans in a shared workspace.

  Safran Group (Factory of the Future)[15] describes the advantage derived "Greater productivity, quality and flexibility, less arduous work, improved ergonomics: the advantages of using robots on production lines are well known, and they are also deployed in a growing number of industries. Over and above pure automation, a very promising new field has emerged, namely "Cobotics", or collaborative robots. ..... Cobotics allows us to combine the capabilities of a robot (strength, precision, repeatability, etc.) with people's specific skills (know-how, analysis, decision-making, etc.). The operator and robotic system work together directly or by remote control, or even with an exoskeleton that multiplies the capabilities of the human body."

  Ireland's Focus on activities related to (Adaptive) Co- and Ro- Botics should be increased training of technical staff in their use and application and development and demonstration of applications relevant to industry in Ireland. In addition to this we should focus on developing our understanding of the dynamics of a Human-Robot team and the application of AI & Machine Learning to Robotic task development & performance optimisation. This would mean an investment in either training within companies or the companies recruiting people with the required skills from the higher education sector.

- **Virtual Reality, Augmented Reality and Mixed Reality**

  "In the context of manufacturing and product design, Virtual Reality (VR) digitally simulates a product or environment, often with the user being able to interact and immerse themselves within it. With Augmented Reality (AR) the digital product or information is projected on to a real

world background, rather than a digitally simulated one like VR."[16]. Mixed Reality (MR) takes AR one step further and allows for virtual objects to be superimposed against real world scenes allowing for engineering inspection in 3D prior to material being cut.

Implementation of these technologies across supply chains allow for distributed approach to design in both product and process design, ensuring faster design cycles and economies in implementation.

Ireland's Focus on activities related to VR and AR should include product and process design, including virtual testing and compliance evaluation, virtualised training, production modelling and optimisation as well as supply chain modelling and integration. This will involve development of AR, VR and MR services including programming, solution design, data analysis and training.

- **Digital Networks and Data Analytics and Cyber Security**

  Digital engineering, supply chain integration, distributed sensor networks and process monitoring (indicative applications of Smart Factory/ Factory of the Future applications) with embedded analytics will lead to the creation of "huge" data sets and demand rapid improvement of ICT capabilities, both in terms of infrastructure and skills. A key aspect of this will be to provide real demonstrations for Ireland's industry base to understand how analytics will improve their businesses.

  Whilst not of immediate relevance to Ireland, in the short-term hardware-software integration (IIoT) will become increasingly important as manufacturing systems and products become self-configuring, self-optimising and self-diagnosis becomes the norm. In addition, data centric business models will come to the fore as manufacturing becomes increasingly customer-centric and the "one off" becomes the norm.

  The foregoing will drive the implementation of appropriate IIoT solutions which are currently at a developmental stage in terms of standards, methods, applications and cyber security.

  Ireland's Focus on activities related to Digital Networks and Cyber Security will be driven by the demand for data analytics - data management and security, safe communication networks, data merge and integration, and then in the area of analytics deep-learning, the analysis of data to facilitate predictive analytics and along with tools (visualisation and analytics tools) to convert manufacturing processes into commercially valuable insights.

  Connectivity is a cornerstone of Industry 4.0 and Engineers Ireland strongly welcomes the Government's commitments made under the National Broadband Plan and, more recently, DCCAE signing the 5G Declaration for Europe.

Case Study 2 3D Metal Printing, SEAM

3D Metal printing (Additive Manufacturing) technology is changing how manufacturing of complex engineering components will be achieved not just in future but for applications today. Metal 3D printing allows the manufacture of complex shapes directly from CAD design to near-net-shape components. This is a rapidly growing disruptive innovative technology and many novel applications of which are only beginning to be understood. SEAM Technology Gateway Centre based within Waterford Institute of Technology is currently playing a key role in translating the potential of 3D Metal Additive Manufacturing (AM) Technologies to Irish based companies. SEAM has an excellent track record in the development of novel applications utilising this technology. This ranges from the creation of techniques for the manufacture of thin wall structures for use in biomedical implants to the optimisation of post processing techniques for part finishing and cleaning.

One specific initiative developed in house at SEAM is the development of sensor encapsulation techniques for the use with metal printing. This allows the inclusion of intelligent sensing devices within metal structures which greatly enhances the functionality of components and can help reduce the mass of high value assemblies such as those used in satellite communication systems. The first such component was the inclusion of the temperature sensor within the body of a metal printed component.

This is envisaged to enable the inclusion of temperature sensors within temperature critical components such as turbine blades in a jet engine (see picture below) or chemical processing equipment. This enables precise control of these systems and also increased reliability due to better monitoring of component temperature. SEAM's venture into such conceptual project is paving the way for further development of embedded sensor technology such as the inclusion of accelerometers, gyroscopes, humidity, pressure and a myriad of other sensor types within metal printed devices. SEAM is continuing to pursue this novel field of development and it is hope it can be expanded to bring benefits to other engineering fields such as biomedical where sensor elements can be included with the casing of biomedical implants leading to more accurate patient biotelemetry and thus improved clinical outcome for patients. This reinforces SEAMs position as a leader in innovation in Metal AM technology development.

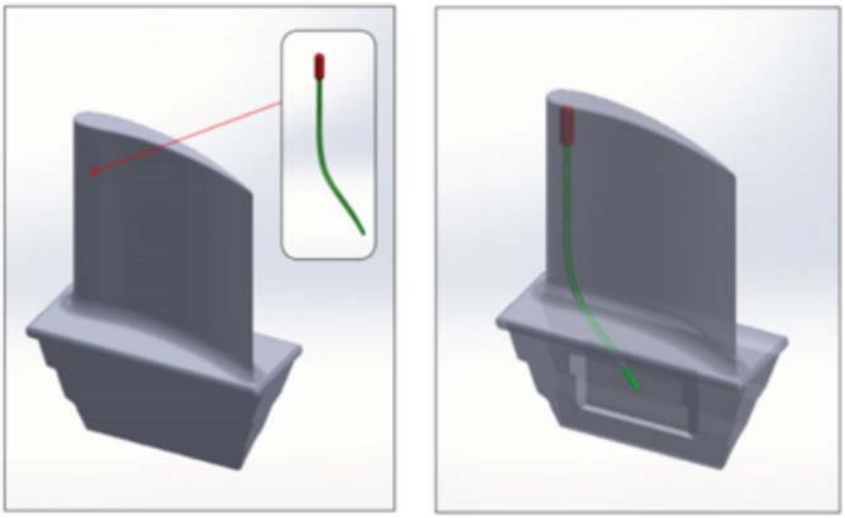


Figure 3 - Senor Encapsulation in a turbine blade using 3D Metal printing technology

Case Study 3 Robotics with Automation

Kuka Robotics, based in Ireland, work with DesignPro in implementing automation projects for both both Irish clients and MNC's. As part of the process of designing a solution for the customer (both Irish clients and MNC's) which would require a suitable robotic system. As part of the proof of concept work would entail the use of digital simulation using KUKA SimPro (based on Visual Components) to create a digital twin of the proposed solution which has the benefit of proving reach and accessibility analysis as well as accurate cycle times. (This creates an absolutely accurate cycle time as well as creating the actual robot program. In the digital twin this can be coded for PLC interfaces so that the line can be virtually commissioned before ever cutting material. Additionally this can then be used for operator training on the cell without ever touching the real world assembly). Once design is outlined, an actual equipment proof of concept trials are performed using components available in the R&D department in order to keep the costs as low as possible, as well as using an existing suite of Kuka robots, transfer mechanisms, servo motors and general PLCs that are available ex stock. 3D printing or some CNC parts is also an avenue that is used to proof out the concept in a simple manner with a minimum amount of moneys invested.

Once both parties enter into a contract, from here, internal Quality Management System procedures control the smooth development through each phase, beginning with project management, who ensure that milestones are reached and that the customer is frequently updated on the development. This would include visuals such as photographs /simulations, short videos during the manufacturing phase and providing written progress reports as required. DesignPro utilises a client portal, which allows the client access to their unique and confidential page.

Once the project has moved to the testing phase and, Kuka and DesignPro try and simulate every possible error and problem on the machine. Where appropriate the client is encouraged to get involved during this phase. Technicians / Engineers relevant to this project visit DesignPro's premises as their knowledge of the customer product is of invaluable support to our debug process. Simultaneously the Technician / Engineer will learn about the functionality and operation of the machine. Post implementation the possibility of remote access remote to the system for fast diagnostics and machine production time can be included.

Figure 4 - Robotic System for Pick and Place in simulation programme (courtesy of Kuka Ireland)

3. Recommendations

We believe that these recommendations will substantively address the issues highlighted above and set Ireland firmly on the road to maximising the potential inherent in applying Industry 4.0 principles to manufacturing systems.

1. Awareness - building and collaboration

- Government, DBEI, DCCAE and DES (and their agencies), should work together to encourage media in Ireland (written, audio and visual) to create editorial on the implications of digitalisation and new technologies for Ireland. In effect, this will mainstream debate and work to our national advantage as the discussion will become truly multi-sectoral.

- Ireland should make a policy decision to seek to become a member of the international alliance 'Platform Industrie 4.0'[17] and become an active partner in an international collaboration developing key aspects of digital manufacturing including:
    - Reference architectures, standards and norms
    - Technology and Application Scenarios
    - Security of networked systems
    - Legal framework
    - Work, education and training
    - Digital business models in Industrie 4.0

- It should be government policy to negotiate bilateral agreements with other member states to gain access to their demonstrator facilities, whilst we build experience leading to building domestic demonstrator facilities relevant to Irish Industry, ideally built within existing centres.

- A national Industry 4.0 Ireland portal (Industry 4 Ireland) should be established in partnership with multi-national companies (MNCs), Research Performing Organisations (RPOs) and appropriate Government Agencies. The portal, providing information targeting SMEs, should primarily provide links to current best practice, national infrastructure (i.e. Technology Gateways, Technology and Research Centres), Advanced Manufacturing Technology (AMT), education and training programmes, training materials, much of which is already available through existing web sites. This could be an initial deliverable of the proposed Industry 4.0 SkillNet (next section).

- Large Items of Research Equipment (LIRE)[18] should be expanded to reflect the full scope of the national infrastructure, both human and equipment, that can support manufacturing industry RD&I activities. This information should be more easily accessible for industry in Ireland. An attempt should be made as a matter of urgency to agree terms of access across all RPOs – industry will be more inclined to engage once the terms of engagement are understood.

- A specific focus of the Enterprise Ireland Innovation Voucher Scheme should be to promote its use as a tool for SMEs, ideally in collaboration with other companies, to work with relevant RPOs and begin the Industry 4.0 journey. Other existing national RD&I supports available through a number of Agencies, can be used to develop ideas further.

- A schedule of regional workshops with speakers representing RPOs and other bodies should be run on a regular basis. This can only be of benefit to both participating companies and the RPOs. This action could be led by Engineers Ireland.

2. Education and re-skilling employees

With the increasing use of technologies, "digitization will create new jobs, but it will also eliminate old ones – mostly unskilled ones. We have seen that in every structural transition to date. If the net balance is to add more jobs, we must concern ourselves with qualifications. Our goal must be to take people with us on our journey by providing them with training and development."[12]. This will lead to demands for higher-skilled jobs with increased contribution to existing value chains. It is critically important that we now start to develop the correct combination of skills, knowledge and competences14.

- HEIs should be encouraged to develop programmes of study addressing the new areas under Digitalisation.
  Traditional third level offerings need to bridge the existing demarcation between operation and information technology. Engineers in the future will need a broad range of skills that encompass mechatronics, instrumentation, automation, electronics, network communications, realtime systems, middleware software development, application development, security and strong communication skills.
- Data capture, analytics and critical evaluation should become standard subjects in degree (both Bachelor and Masters) level courses.

- To reflect the inter-disciplinary nature of Industry 4.0, social skills including team building and communication should become core subjects. Multi-disciplinary project work should be promoted across our HEIs.

- Apprenticeship courses should be updated to include applications of digital technologies – consideration should be given to the German/ Austrian qualification of Production Technologist that included content that can readily be adapted to Industry 4.0.[19,20,21]

- A structured Industry 4.0 SkillNet should be established in association with Engineers Ireland's CPD programme and with a strong focus on data analytics, technology and awareness building and examples of international best practice.

- Enterprise Ireland should investigate the possibility of applying the 'BioInnovate Ireland' model to manufacturing[22] – "Innovation 4 Industry". The Fellowship Programme (with placements both nationally and internationally) should strive to quickly determine international best practice and move rapidly to identify market needs, building consortia of companies and relevant RPOs to develop and commercialise solutions. These activities will also help in the formulation of focused, dynamic training modules for industry in Ireland.

3. Measures to support RD&I spend and capital investment

- Legislation should be introduced to allow for the maximum level of funding for national R&D support schemes in line with published State Aid Rules limits.

- Strategic Banking Corporation of Ireland operational practices should be reviewed to ensure competitive terms are available to industry in Ireland[23] and the State should consider establishing a loan scheme similar to that provided by "bpifrance"[24], Finnvera[25], AWS (Austria)[26,27] or KfW (Germany)[28].

- Further to the above, a review should be carried out of the increasing number of supports (both new and revised existing mechanisms) available through the European Commission sponsored programmes, to ensure that industry in Ireland is deriving maximum value from same.

- The Department of Finance should consider introducing a system of accelerated depreciation of capital equipment related to implementing an Industry 4.0 strategy, as per the Italian model[29], to further support SME investment in new technologies and practices. In many cases these investments will be critical to industry remaining internationally competitive.

4. Co-ordination and collaboration of activities across the national response

It is critically important that Ireland is not losing opportunities through duplication of effort across RPOs or, indeed, missing opportunities for collaboration. Securing Ireland's manufacturing future is becoming ever more important as the level of investment is increasing and spread over many RPOs. The Knowledge Transfer Ireland web portal[30] lists 28 manufacturing related centres (see page 16) with an additional 25 involved in ICT and data analytics relevant to the sector.

- Whilst each Centre is impressive, both in terms of capability and support offered to industry, Ireland will benefit through increased collaboration across relevant RPOs. This collaboration should be encouraged across sectoral boundaries in order to address the truly disruptive nature of Industry 4.0.

- Mechanisms to encourage and monitor collaboration should be agreed between Enterprise Ireland, the IDA, Science Foundation Ireland and the funding bodies supporting the National Centres with action being taken locally amongst RPOs to deliver synergies that will benefit industry in Ireland.

- Co-ordination of national efforts could be managed through the Technology Centres, working closely with the Technology Gateways - their proximity to industry in Ireland (MNC, SME and High Potential Startups (HPSUs)) puts them in an ideal position to lead the national Industry 4.0 effort, supported by the Research Centres. Were this model to be rolled out then the Centres would have to be adequately resourced to maximise the positive impact for Ireland.

Comment

In the course of developing the policy document, a number of other areas of interest were raised which fell outside the scope of this policy but which might provide avenues of future research and developments into polices such as: Sustainability in Manufacturing (including Energy Usage, Second Life of Products), Biopharma 4.0, and BioEngineering.

Relevant Research Performing Organisations

Technology Centres/ National Institutes

Irish Manufacturing Research

Tyndall National Institute
Institiúid Náisiúnta

DPTC
DAIRY PROCESSING TECHNOLOGY CENTRE

PMTC
Advanced Technology Solutions in Pharmaceutical Manufacturing

MEAT TECHNOLOGY IRELAND
STRATEGIC INNOVATION, MAXIMUM IMPACT_

NCLA

nibrt
National Institute for Bioprocessing Research and Training

Technology Gateways

APT
Applied Polymer Technologies

CENTRE FOR ADVANCED PHOTONICS & PROCESS ANALYSIS
CAPPA

CREST DIT
TECHNOLOGY GATEWAY

DESIGN+
Bioscience · Engineering · Computing

IMaR
Technology Gateway
INTELLIGENT MECHATRONICS AND RFID

met
medical & engineering technologies

MICRA
Microsensors for Clinical Research and Analysis

PMBrc
Pharmaceutical & Molecular Biotechnology Research Centre

PEM
Precision Engineering & Manufacturing

SEAM
South Eastern Applied Materials Research Centre

Shannon ABC
applied biotechnology centre

TEC @ NIMBUS

WISARLab

IComp
Irish Composites Centre

Research Centres

AMBER

Confirm
Smart Manufacturing

cúram
Centre for Research in Medical Devices

I-Form
Advanced Manufacturing Research Centre

Lero

MaREI
Centre for Marine and Renewable Energy

SSPC
SYNTHESIS AND SOLID STATE PHARMACEUTICAL CENTRE
Innovation Through Collaboration

(Adapted from Knowledge Transfer Ireland, Research Map of Ireland[30])

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The committee would like to thank those who took the time to respond with their considered thoughts and we hope that we have incorporated these into the document.

About Engineers Ireland

With over 25,000 members from every discipline of engineering, Engineers Ireland is the voice of the engineering profession in Ireland. Engineers Ireland was established in 1835 making us one of the oldest and largest professional bodies in the country. Members come from every discipline of engineering, and range from engineering students to fellows of the profession.

Our responsibility is to

- **Promote knowledge of engineering**
- **Establish and maintain standards of professional engineering and engineering education**
- **Provide opportunities for Continuing Professional Development (CPD)**
- **Maintain standards of professional ethics and conduct**
- **Ensure that professional titles are granted to qualified candidates**
- **Act as the authoritative voice of the engineering profession in Ireland**

Our Vision

A community of creative professionals delivering solutions for society.

Our Mission

Engineers Ireland is an organisation that enables the engineering community to progress their professional development, make an impact on society and encourage and educate the future generations of engineers.

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