



# NEXT GENERATION SUPPLY CHAINS: MAKING THE RIGHT DECISIONS ABOUT DIGITALISATION



Published by the University of Cambridge Institute for Manufacturing

Title: Next generation supply chains: making the right decisions about digitalisation  
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# NEXT GENERATION SUPPLY CHAINS: MAKING THE RIGHT DECISIONS ABOUT DIGITALISATION

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Supply chains are on the cusp of transformation. Tantalising opportunities to 'connect' previously disparate upstream and downstream operations are within the reach of supply chain strategists. We are already seeing disruptive changes in many industries and we envisage this process is only going to accelerate. In this context, the organisations most likely to prosper are those that fully embrace the new technologies, gaining insight and advantage through rapid experimentation and early adoption.

Companies are already making significant investments in digital supply chains because they recognise that digitalisation will give them four big – and connected – prizes: integration, transparency, productivity and, ultimately, the opportunity to transform their supply chain operating model. It has the potential to turn a supply chain director's dream into reality: the ability to join together inbound, internal and outbound networks with complete real-time visibility.

The goal? To create a vastly more responsive and resilient network that delivers better quality products and services to its customers. And, by automating business processes and inter-company transactions across the network, being able to do all this *and*, ultimately, make huge savings as well. But it's not just about making incremental improvements to existing business processes. The biggest prize of all is a reconfigured operating model that transforms the way an organisation meets its customers' needs. This is also, arguably, the biggest threat. If the

large, slower-moving incumbents do not take decisive action they may suffer at the hands of smaller, more agile players who – in this digital world – are better placed than ever before to disrupt an entire sector.

Although the benefits sound compelling on paper, realising this vision of an end-to-end digital supply chain remains elusive for many large global businesses. It involves major transformation both at a conceptual level and in execution. While thought leaders and change agents within companies may focus on the prize, CEOs and shareholders are often much more cautious given the levels of investment and organisation-wide disruption it entails.

This is particularly the case for the global giants with a history of merger and acquisition and an array of legacy systems to integrate. The risks are undoubtedly significant and with technology and the business context changing so fast, at what point do you pin your colours to a particular digital mast?



**DR JAG SRAI** is Head of the Centre for International Manufacturing at the University of Cambridge's Institute for Manufacturing.

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This white paper is based on research carried out by the IfM's Centre for International Manufacturing and insights emerging from our work with industrial partners. In it we share our latest findings to help global companies consider their digital supply chain strategies.

# UNLOCKING THE DIGITAL SUPPLY CHAIN

Digital supply chain transformation projects are not about doing everything at once. Instead organisations need to consider the scale of the opportunities across the supply chain and the risks involved, then prioritise those technology interventions that impact most on supply chain operations- and deliver outcomes that best support corporate strategy.

The starting point for sound decision-making has to be a clear understanding – or conceptualisation – of the end-to-end digital supply chain. But that is by no means as easy as it sounds. Our research team looked at dozens of models that are currently being used to conceptualise the digital supply chain. Many of those models are based on Industry 4.0 thinking. The example shown here (right) is typical<sup>1</sup>, couched in terms of the nine technologies transforming manufacturing.

While this model is helpful in giving an immediate overview of the key components of Industry 4.0, it is not clear how they might impact the supply chain. And, as the diagram shows, there is an array of digital interventions and technologies that organisations could look to implement. Some elements relate to necessary infrastructure, some to data and others to enhanced technical capabilities. What does this mean for supply chain strategists and how can they use these technologies to redesign their supply chains?

At the Centre for International Manufacturing we have been thinking hard about how to frame the latest research into digital supply chains in a way that is much more useful for senior operations managers and supply chain professionals.

We have been doing this in a number of ways: tracking activity across key industrial sectors and working on major projects within some of those sectors. We have also been working closely with a small number of multinationals in a pre-competitive forum set up specifically to address the digital challenges and opportunities they are facing in their supply chains.

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Organisations need to consider the scale of the opportunities across the supply chain and the risks involved, then prioritise those technology interventions that impact most on supply chain operations

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<sup>1</sup> OCED, 2017, adapted from 'Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries', Rüsmann et al. 2015

*Industry 4.0 – the nine technologies transforming manufacturing<sup>1</sup>*

# UNDERSTANDING INDUSTRY TRENDS

Generic examples of digital adoption	Industries where prevalent	Current maturity / application
Digitalisation of service supply Mass connectivity – consumers <-> suppliers	Media, financial services e.g. Insurance Sharing economy e.g. Airbnb, ‘uberization’	VERY HIGH 
ICT enabled product personalisation Consumer convenience/immediate gratification	e-Commerce B2C firms, mass customisation Online sales with rapid last mile distribution	VERY HIGH 
Rapid advances in & lower costs of automation Production modularity & real-time scheduling	Production asset intense B2B industries Production flexibility for high SKU industries	HIGH 
Big data driven predictive supply chains Use of demographic data to plan future needs	Retailers, FMCG - seasonal/promo products Healthcare solutions, public service provision	MEDIUM 
Manufacture to order, close to the point of use 3D printing (small scale items)	Makerspaces for local manufacture Service firms with requirements for spares	MEDIUM 
Remote monitoring of industrial equipment Monitoring product use in the home	Through-life product servicing e.g. aerospace Intelligent white goods e.g. ‘smart’ refrigerators	LOW 
3D printing (complex/large scale items) Continuous production processing	Superior product design +/- use functionality Batch process industries seeking vol. flexibility	LOW 
Ensuring product provenance, compliance End-to-end supply visualisation	Regulated industries; Pharmaceuticals, Food Enterprise Data Systems e.g. ‘watch towers’	VERY LOW 

Industry trends in adopting digital supply chain technologies<sup>2</sup>

Where along the supply chain have firms been focusing their digital energies to date: upstream, within the factory, downstream or across the end-to-end supply chain?? It is clear that different sectors are clustering around different activities. And this is important for understanding where the opportunities lie.

It is also clear that cumulatively these decisions are starting to have a direct and significant impact on the way sectors are currently structured. This is going to have implications for both incumbents and new entrants and for skills and employment across the board.

**In the next section, we consider in more detail the industry trends upstream, downstream and across the end-to-end supply chain.**

<sup>2</sup> Srai J.S., input to, and reported in: Investment and the digital economy: World Investment Report 2017. UNIDO



# ADOPTION PATTERNS ACROSS THE END-TO-END SUPPLY SYSTEM

## UPSTREAM

Many multinationals are already embarking on their digital journeys and we are seeing some clear trends emerging. In sectors such as automotive, aerospace and maritime – where manufacturers are procuring large volumes of components – digital projects tend to focus on upstream supplier relations. We are also seeing similar behaviours in consumer electronics, where companies need to source and assemble large numbers of often complex components.

Firms are finding that by integrating and automating their purchasing processes, they are both increasing productivity by eliminating activities such as order raising and progress chasing and minimising subsequent disruption in their manufacturing operations. eAuctions, Vendor Managed Inventory and a more collaborative approach to the design of both products and production processes are all areas in which we are seeing increasing investment.

## WITHIN THE FACTORY

Unsurprisingly, factory design and digitally-enabled production processes are key for **production intensive** sectors. Many of these firms are investing in more flexible automation and collaborative robotics. They are also using data derived from sensors to develop smarter systems that will optimise factory scheduling and minimise disruption.

As for new production processes, we are seeing continuous manufacturing beginning to have an impact on the pharmaceutical sector heralding potentially seismic disruption for its existing supply chains. 3D printing is also starting to play a part particularly in the discrete assembly industries, in the production of prototypes and for small scale items and spares. Clearly, it has the potential to revolutionise business models and supply chains, with manufacturing becoming smaller-scale, close to market and able to deliver mass customisation.

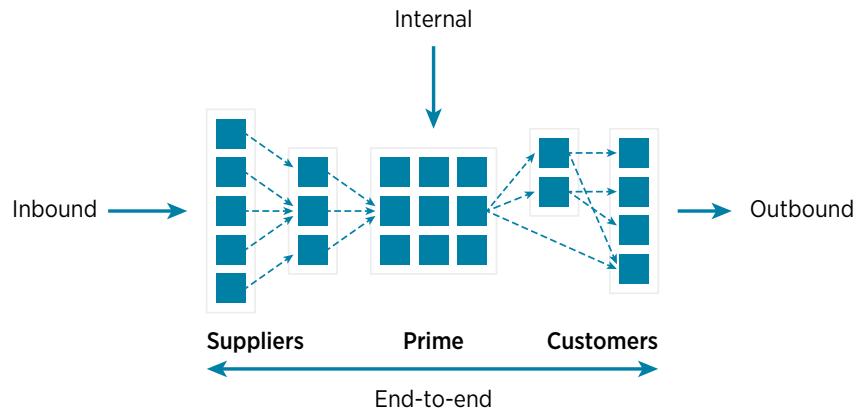
However, while sectors such as aerospace – which rely on high performance, high cost components – are early adopters of 3D printing, for manufacturers of high volume, fast moving goods there is still a way to go in understanding what impact it will have.

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One of the risks for firms that are hesitating about investments in digitalisation projects is that those who are setting the pace are not only seeking competitive advantage but are also changing the rules of the game for everyone else.

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*Scoping the end-to-end supply chain*

## DOWNSTREAM

Service providers, particularly in the sectors such as financial services, FMCG and retail are focusing on the value they can get from digital downstream activities where there are a number of changes taking place. On the one hand, digital platforms are supporting increasing disintermediation with companies able to cut out local resellers and go directly to market. On the other hand, the big online retailers such as Amazon are becoming increasingly powerful. In both cases, being able to deploy reliable and rapid 'last-mile' distribution is becoming a key differentiator in the e-commerce retail sector.

Big data analytics is also a transformative opportunity for companies operating in this space. Insights into customer behaviour are driving both incremental improvement to products and services but also underpinning business model innovation.

## ACROSS THE END-TO-END SUPPLY CHAIN

There are, of course, sectors for which digitalisation across the supply chain is important. In highly regulated sectors such as pharmaceuticals and food production, for example, where track and traceability is critical to establishing the provenance of goods, digital clearly has a vital role to play. And with manufacturers increasingly providing 'through-life' servicing for anything from planes to 'smart' fridges, having an integrated view of the whole supply chain is becoming more and more important in other sectors too.

Enterprise Data System providers, through working with client manufacturing firms, are now offering 'watchtower' solutions that can provide real-time monitoring of data across multiple systems and devices; this enhanced transparency within a supply chain can support much greater flexibility and agility in managing production and supply. In this new world, ownership of the data becomes critical – something that not enough companies have been sufficiently alert to. Where partners are actively involved, who owns and has access to the data becomes a key question.

Data sharing and connectivity also raises the question of open source versus 'black box' and developing common international data standards across sectors. In this area we must also consider the resilience of these digital supply chains and understand the cyber security challenges they may present.

## WHAT DOES THIS ALL MEAN?

All of these developments have implications for international manufacturing. Upstream supplier relations are being transformed as existing suppliers are facing increased competition in a more open, dynamic and potentially more collaborative procurement system. Factory automation and intelligent processes are creating more high value jobs and increasing productivity but this is likely to have consequences for net levels of employment.

As OEMs build smarter factories, one of the consequences is that their partners and suppliers are being asked to increase their own technology levels which they might not be in a position to do. Disintermediation is also having a disruptive effect on service and supply partners and encouraging new market entrants with completely different business models.

One of the risks for firms that are hesitating about digitalisation is that those who are setting the pace are not only seeking competitive advantage but they are also changing the rules of the game for everyone else.

For firms that are thinking about their own digital supply chain strategies, one of the key challenges is to move beyond what the technologies *are* (the Industry 4.0 shopping list) and think about what they can *do*.

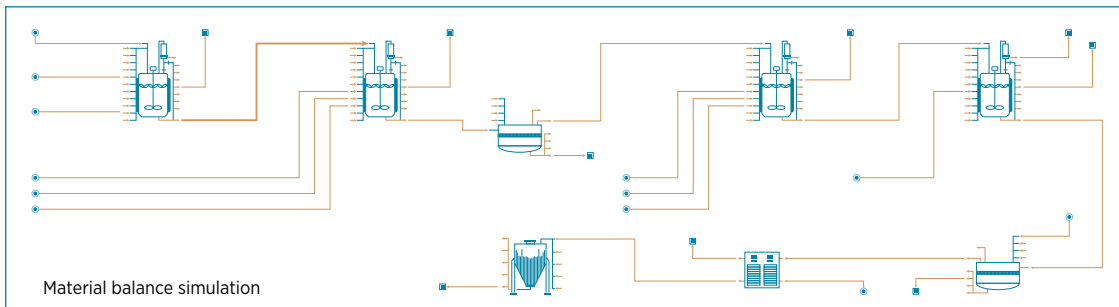
# TOWARDS A NEW FRAMEWORK

As a research centre, our principal focus is on how to design manufacturing supply networks; how can you bring together different layers of analysis into a framework that can drive effective decision-making. Today's multinationals have

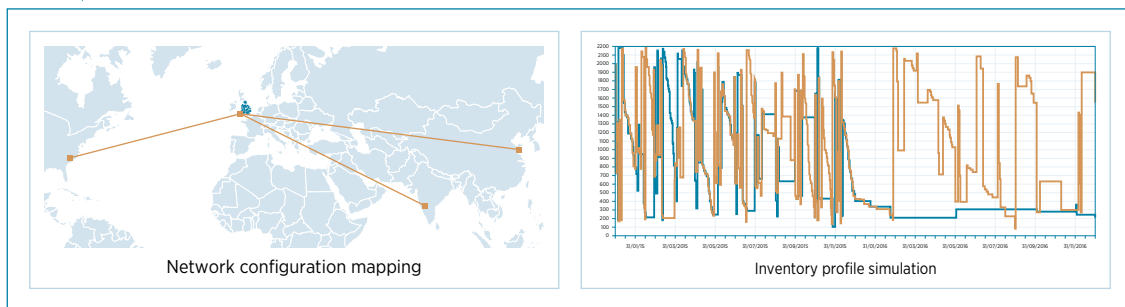
highly sophisticated digital mapping tools (illustrated below) that can, for example, help an operations manager reduce lead times. Meanwhile, elsewhere in the same company, a supply chain executive may be looking at where best to locate a new

factory in order to serve a particular market. At the same time, the Board might be worrying about how to both minimise the firm's environmental impact and ensure its long-term sustainability in the face of dwindling natural resources.

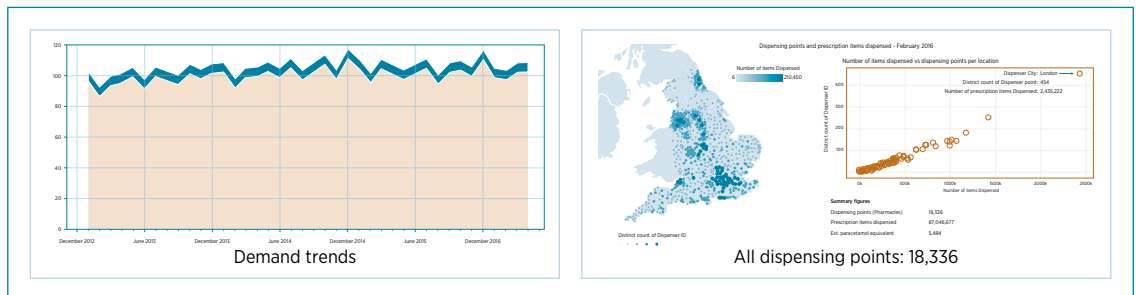
## MICRO-LEVEL: UNIT OPERATIONS MODELLING



## MESO-LEVEL: SUPPLY NETWORK ACROSS FIRMS & COUNTRIES



## MACRO-LEVEL: AGGREGATED PHENOMENA OBSERVED AT SPECIFIC GEOGRAPHICAL AREAS OVER TIME



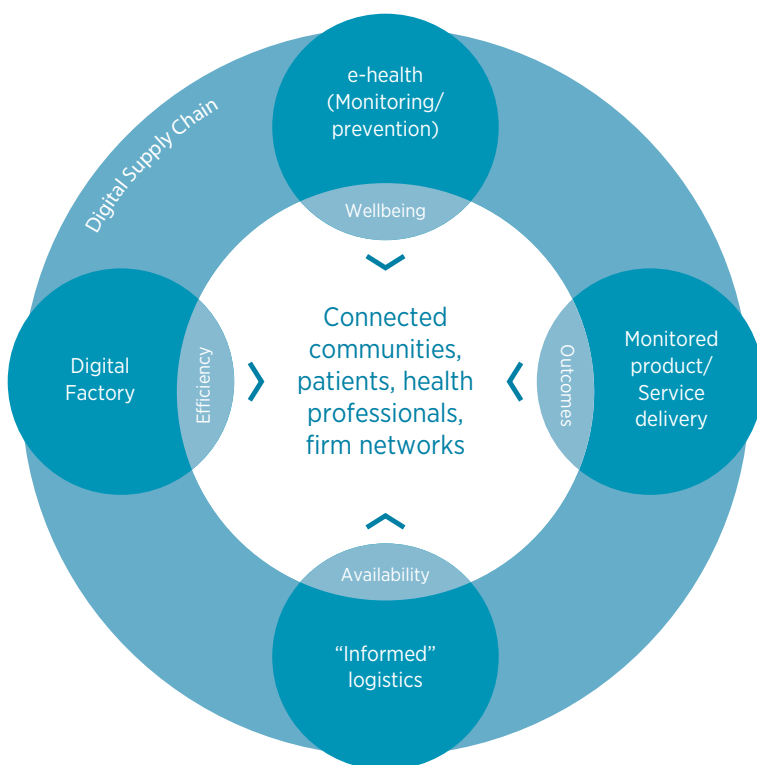
*Digital supply chain mapping at micro, meso and macro levels (adapted from Settanni, E., and Srari, J.S., working paper)*

Sensors, connectivity, the cloud, internet of things, big data: these are all the building blocks for transformation but they must not be mistaken for the transformation itself.

The challenge for most organisations is how to integrate these different levels of analysis – and potentially conflicting objectives – into a coherent, company-wide strategy, that encompasses technologies, processes and, crucially, people.

Sensors, connectivity, the cloud, internet of things, big data: these are all the building blocks for transformation but they must not

be mistaken for the transformation itself. To maximise success, changes to the digital supply chain must reinforce strategic objectives, so there needs to be a clear focus on what organisations are trying to achieve: increased efficiency and productivity, better quality products and better service to customers both in terms of availability, delivery and outcomes – does the product work and continue to work throughout its life?



The Centre for International Manufacturing has created a very different framework to the typical industry 4.0 models (generic conceptualisation illustrated on this page). It looks across the supply chain to identify distinct types of activity, the roles they play and the outputs they deliver. This framework shows the range of interconnected activities throughout the end-to-end supply chain that each focus on a particular outcome.

By considering the strategic importance of each area and the current and required levels of capability, organisations can start to consider where investments and organisational change programmes would be best focused.

Generic digital supply chains conceptualisation  
 (adapted from Srar, J.S., Harrington T.S., Settanni, E., Kumar, M.,  
 Tsolakis, N., Hennelly P., Trokanas N., working paper)

# CASE STUDY

## UK PHARMACEUTICAL SECTOR

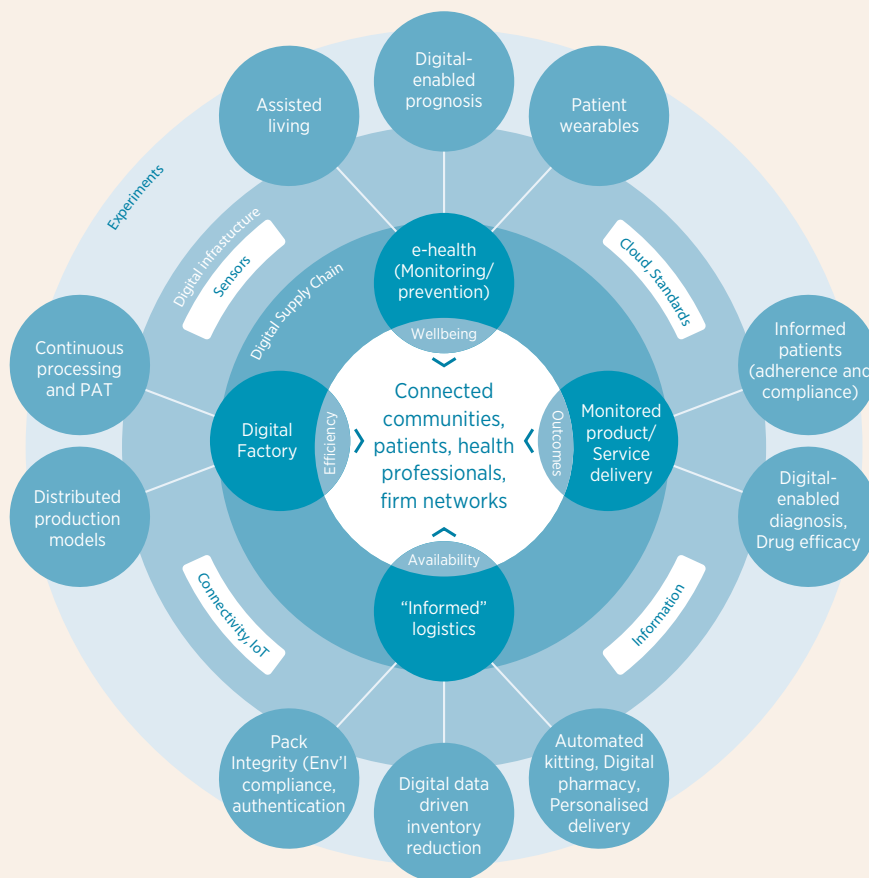
CIM is leading the research for a major UK project, REMEDIES, looking at reconfiguring the UK's clinical and commercial supply chains across the pharmaceutical sector. This £22million project is co-funded by its major industrial partners (led by GSK) and the UK government. Both potential benefits and significant disruption are looming for this key sector, brought about by developments in continuous manufacturing combined with connected, digitalised supply chains. The opportunities to transform a currently resource inefficient sector that operates at unwieldy scale into something that could deliver truly bespoke medical interventions direct to patients are exciting.

For this project we took our generic supply chain conceptualisation and populated it with activities specific

to the pharmaceutical sector. We also added a further layer: experimentation. One of the barriers to digital transformations is the scale of investment required. We have been trying to mitigate this by initiating a number of experiments that can be put into practice quickly and their efficacy measured before committing more significant resource. A good example of this type of experiment is around smart packaging. One of the challenges faced by the pharmaceutical sector is a lack of patient compliance. Around 30% of patients who are prescribed medicines fail to complete the course. In a world of scarce resources this is incredibly wasteful and can have negative societal impacts. As part of the REMEDIES project, the Centre for International Manufacturing has been

exploring the possibilities presented by technologies that are already in widespread use such as QR codes and mobile apps – and how they can help ensure that patients take the medicines they are prescribed.

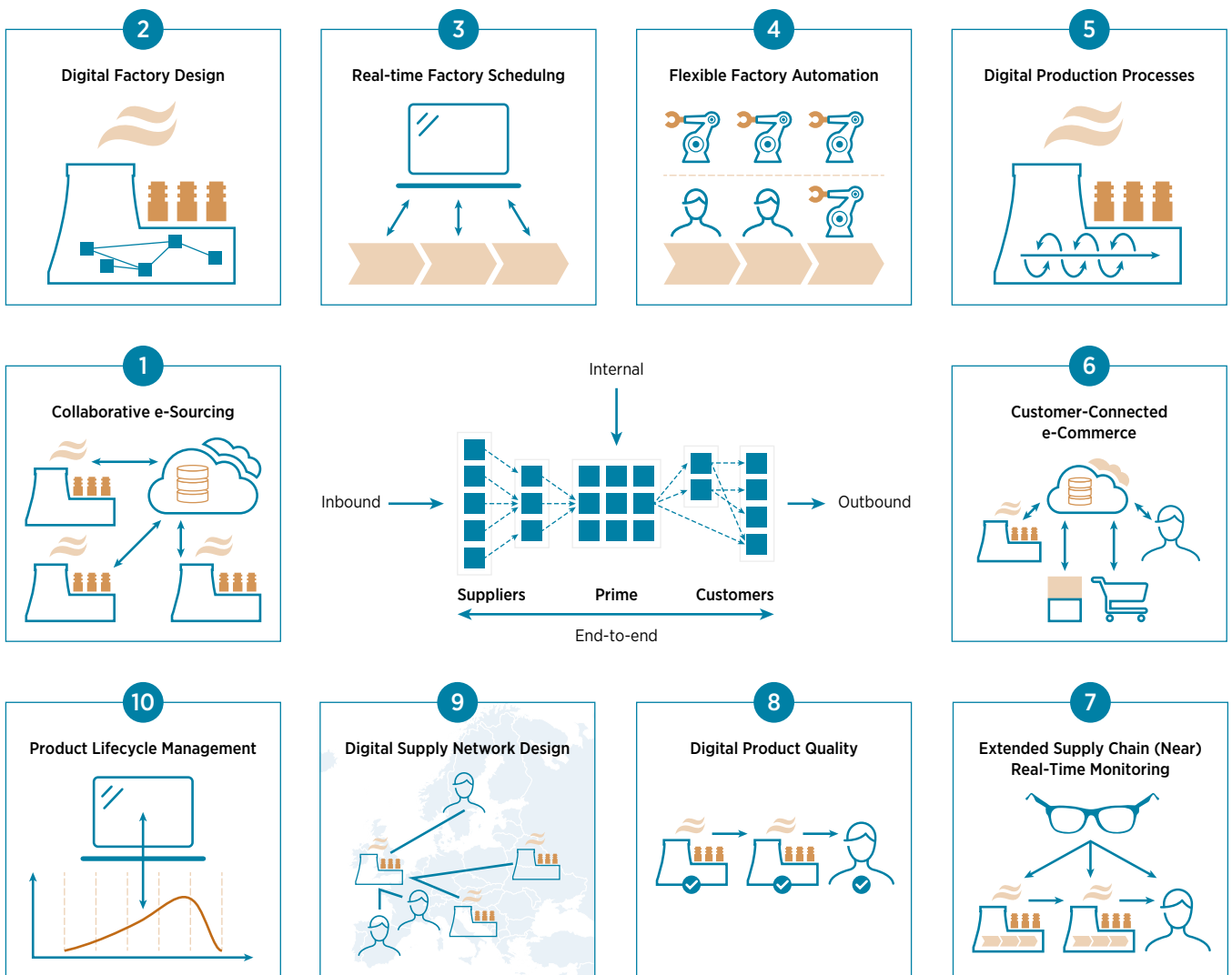
The information supplied with medication is usually provided on a small leaflet that few people read. The REMEDIES team is working on a mobile phone app that will allow patients to read the instructions on their phone (at a font size and in a language of their choice) or listen to some audio or watch a video. This type of experiment is low cost and delivers measurable results which can then support decision-making around the next generation of smart packaging and wearables which have the potential to monitor and support patient care throughout a course of treatment.<sup>3</sup>



<sup>3</sup> "Take your medicine: how new research into pharmaceutical supply chains will help you take care of yourself." *Research Horizons, Issue 33, June 2017*

# DIGITAL SUPPLY CHAIN SCENARIOS

With so many potential opportunities to digitalise different aspects of the supply chain, companies need to take a structured approach to decision-making. To help them do this we have extended our network model and broken it down into a series of digital scenarios<sup>4</sup> covering inbound, internal, outbound and end-to-end perspectives (see below).



<sup>4</sup> The digital scenarios framework (adapted from Srari J.S., Christodoulou, P., and as reported in IfM Review, 2016)

# DIGITAL SCENARIOS: MAKING THE RIGHT DECISIONS

By breaking down the supply chain into a series of digital scenarios we have created a framework for robust decision-making based on a clear understanding of what outcomes companies are looking for.

We have developed maturity models for each of the scenarios in order to help companies think about which areas they want to focus on, assess their level of achievement to date and prioritise their efforts.

The framework starts by defining the practical application of digital technologies at the appropriate stage in the value chain, then the business benefits and challenges, before assessing current and required capabilities in terms of both technology and skills, then finishes with assessing achievability.

## DIGITAL SUPPLY CHAIN SCENARIOS



### 1. Collaborative e-sourcing:

Whilst EDI and automated call-off are well-established forms of digitalised sourcing, companies are seeking to extend this to cover tiers beyond direct suppliers and to include proactive warning systems. Increasingly, the sourcing bottlenecks, or the materials vulnerable to supply disruption, are further back in the chain and digital systems can improve visibility. Furthermore, companies are seeking deeper strategic engagement with suppliers and higher levels of trust –

key aims that need to be included within a digital procurement strategy.

In this context we defined the highest level of maturity as: “Seamlessly connected, automated replenishment from the supplier network (multiple tiers) with real-time KPI monitoring and predictive disruption analysis”. We then ask companies to score themselves as to how significant they consider the opportunities and benefits this could bring as well as the challenges and uncertainties. The next step is to consider how mature the current enabling technologies are now and over the next five years and how well developed are their organisational skills, know-how and attitudes.

By repeating this process for the other nine scenarios outlined below, companies can develop a clear picture of where they need to focus their energies in order to achieve their strategic objectives.



### 2. Digital factory design:

Digital 3D modelling systems for factory design are becoming increasingly sophisticated. Coupled with the advent of flexible manufacturing systems and data connectivity, these advances provide the stimulus for a new paradigm in factory layout design, process and material flows. As well as looking totally different, tomorrow’s digital factory will have a significant impact on takt time, buffers, skills and manning. It should also be easily reconfigurable in response to changing conditions.



### 3. Real-time factory scheduling:

How we run factories, as well as how we design them, will change dramatically, and this requires a form of digital business process re-engineering. The prize could be huge in terms of increased productivity, improved delivery performance, response to change and fewer missed sales. However, making full use of the sensor-enabled, smart device, real-time opportunity with seamlessly joined-up ERP, MES and cloud systems is not easy. It needs careful navigation to maximise business benefits and avoid costs and complexity.



### 4. Flexible factory automation:

Ever cheaper technology, collaborative robotics, and machine learning mean we are entering a new era of factory automation. The business benefits include lower cost for variety, increased customisation, labour saving, quality assurance, closer-to-market location, and improved health and safety. One important aspect is to introduce equipment modularity and standards into the overall vision, which supports the necessary economies and enables flexible reconfiguration.



### 5. Digital production processes:

The shift towards replacing ‘subtractive’ manufacturing processes (such as machining) with ‘additive’ processes (such as laser sintering and digital printing) has obvious benefits in cost, with arguably even bigger

opportunities in enabling new product designs and enhanced customisation. In addition, these new techniques could bring about the disruptive reconfiguration of complete supply chains and industry sectors. This is clearly an area where companies need to be scanning, and actively experimenting with, the latest technologies.



**6. Customer-connected e-commerce:**

At a minimum, companies should be aiming to extend e-commerce to optimise web-based order management, including personalised configuration, omni-channel access and last-mile delivery. The latter is becoming a key competitive differentiator particularly in retail consumer goods, where 'last-mile' costs are often outstripping the total cost of manufacturing and primary distribution. We are seeing an increase in the number of 'dark stores' the larger retailers are setting up in areas of high population density. In healthcare, the inexorable drive towards more bespoke medicines – both in formulation and delivery – points to where this is all heading. E-commerce in itself is a relatively modest aspiration. Firms are now looking beyond this to completely new business models based on customer-connected supply chains – constantly monitoring product usage and experience, and tailoring the offering to suit.



**7. Extended supply chain (near) real-time monitoring:**

While scenario 4 focuses on flexible digital factory scheduling, there is a wider opportunity relating to the complete, end-to-end supply chain. This involves looking one level higher at the total network, using data science, predictive analytics, real-time risk management, and dynamic resource optimisation – enabled by distributed sensors and track-and-trace to create visualisation 'watch towers', optimise integration, predict disruptions, and support dynamic decision making.



**8. Digital product quality:**

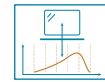
The vision for TQM in the digital context involves end-to-end transparency, real-time root cause analytics and proactive resolution driven by customer connectivity. The challenge is to connect a series of 'traceability islands' back from customers, across internal operation networks, right through to suppliers. The potential benefits are considerable, arising from: faster problem resolution, problem prevention, customer satisfaction, performance, compliance verification and avoided warranties.



**9. Digital supply network design:**

Scenario 2 focuses on digital factory design, but there is also a higher-level opportunity at the total supply

network level. This involves digital network design, modelling and visualisation tools that support deeper understanding of key dynamics and drivers covering cost, responsiveness, risk, resource access, and innovation. The tools also support rapid experimentation in terms of possible future network options leading to breakthrough scenarios and faster transformation. This can lead to totally new network design principles, and step changes in supply collaboration, site location, capacity, inventory and customer response.



**10. Product lifecycle management:**

There is a growing need to integrate product-based data systems with supply chain-based systems, aligned with a single vision for product lifecycle management and value capture. These next-generation PLM systems can provide accurate, up-to-date product information accessible throughout the value chain and product lifecycle. This enables enhanced cross-function and cross-organisational involvement in design, collaborative innovation, design for manufacture/procurement, platform-based design philosophies, quicker time-to-market and improved portfolio management.



# COMBINING DIGITAL CAPABILITIES FOR COMPETITIVE ADVANTAGE

One of the findings to emerge from our review of industry trends (see page 7) was the clustering of different types of digital activity by sector. We have seen similar patterns emerge through the application of the scenarios framework. As you might expect, firms that are very customer-facing are focusing on customer-connected fulfilment, whereas those firms that rely on complex materials and components have been concentrating on collaborative e-sourcing and procurement.

Asset-intensive production operations are looking at scenarios 2 to 5 encompassing the digital factory and companies with an extended network of production sites looking to optimise where they engage with their supplier network are prioritising network design and collaborative e-sourcing.

What we are seeing is the emergence of 'hot spots' – combinations of activities that will lead to competitive

advantage. For example, an FMCG company with an extensive production and supply network may be looking at 'automated collaborative sourcing' and 'digital supply network design' coupled with a customer-connected e-commerce fulfilment model.

Depending on the complexity of the product, real-time factory scheduling and factory flexible automation could be added to that mix. And while that might seem ambitious, when you look at all the potential areas of digital transformation it is still de-prioritising those areas that will ultimately have less impact on the business in order to concentrate on those that will have the greatest.

For companies embarking on the digital journey, perhaps the most important decision of all is deciding which areas of supply chain activity not to transform.

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The areas firms identified as offering the biggest potential prize were flexible factory automation, digital product quality and real-time scheduling. However, these areas were also perceived to be some of the riskiest.

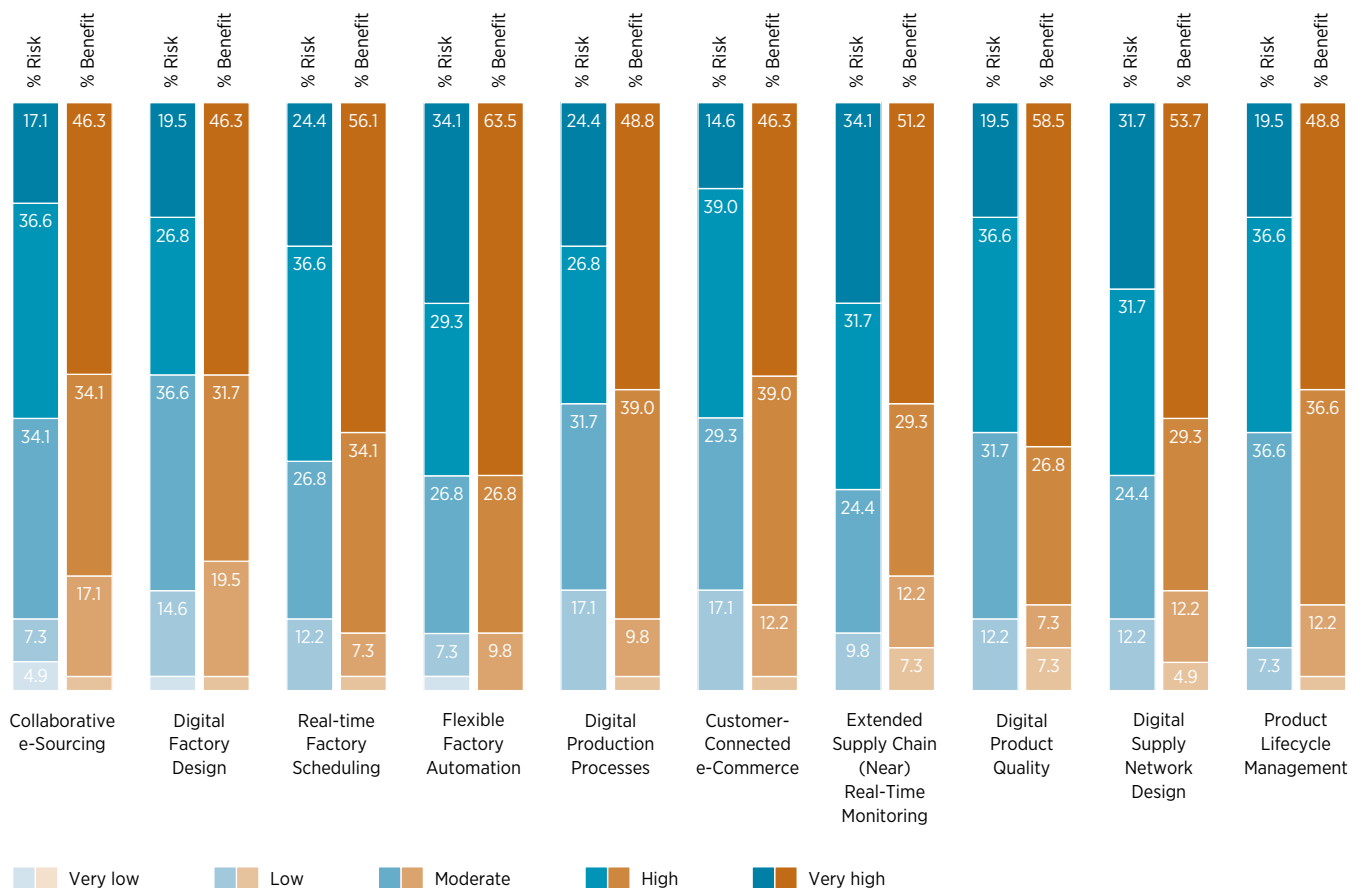
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# CHALLENGES AHEAD

Using the framework with a group of senior executives from some major multinationals, an interesting picture emerged: the benefits of digitalising the supply chain outweighed the not inconsiderable risks.

The areas firms identified as offering the biggest potential prize were flexible factory automation, digital product quality and real-time scheduling.

However, these areas were also perceived to be some of the riskiest. Digital production processes was the area where the benefits most significantly outweighed the risks.



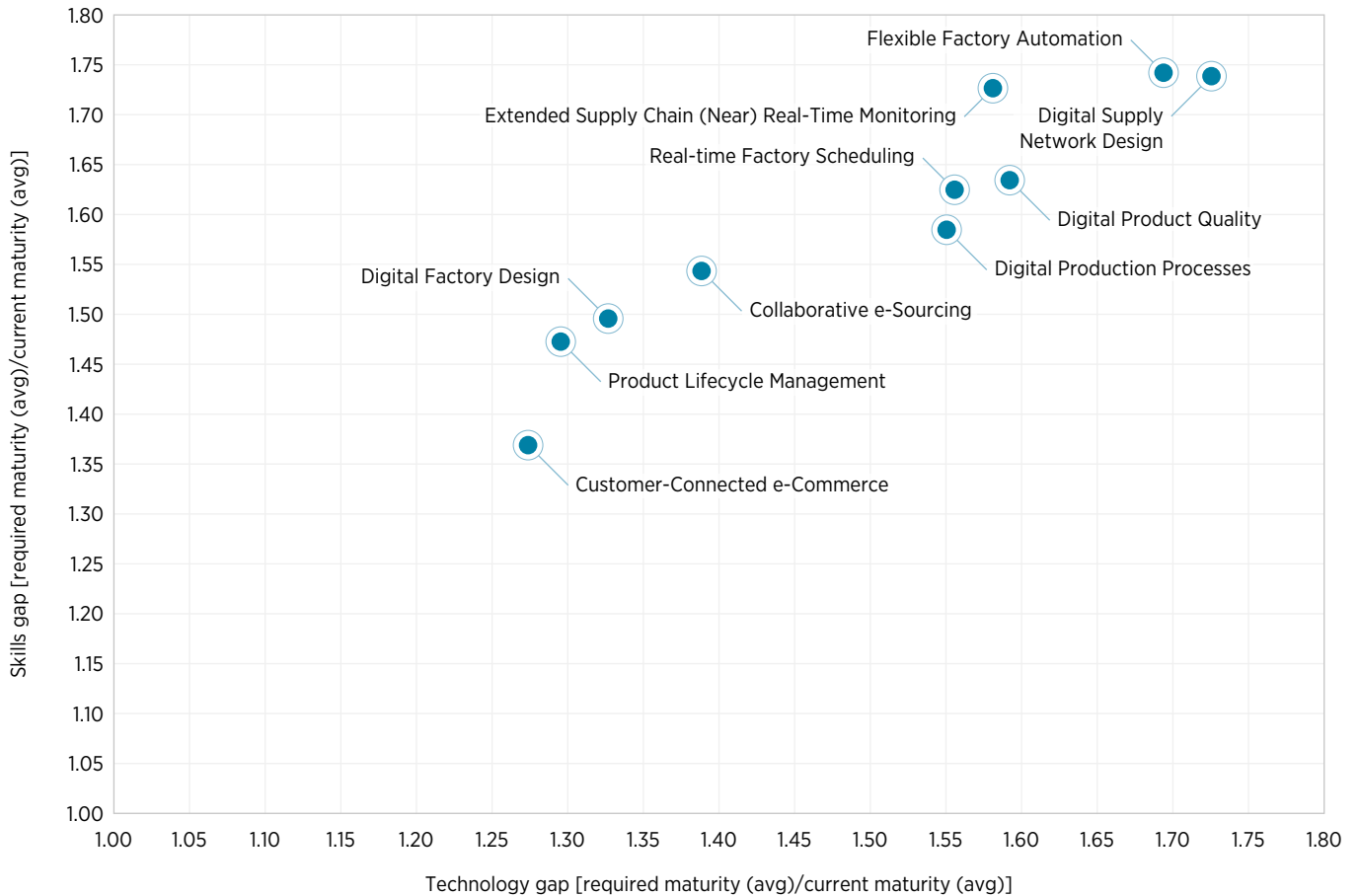
*Risk/benefits for the ten digital supply chain scenarios (adapted from Srar J.S., Settanni E., and reported in 'Application of digital technologies to innovation in manufacturing'. BSI report 2016)*

## CHALLENGES AHEAD

If that overall message is an encouraging one, less positive news pertains to the key barriers to progress. Technology is not the overriding problem. While there is undoubtedly a gap between where firms are now and where they want to be, that gap is not insurmountable. More problematic is the skills gap which was

identified as common across all parts of the business, not least in the boardroom. The graphic below shows that skills gaps were perceived to be consistently (a bit) higher than technology gaps. This finding has been reinforced when we have investigated individual firms in more depth.

And this is not an easy problem for an individual firm to fix. It implies the need for an overhaul of the way digital skills are taught throughout our education system as well as cultural change throughout organisations from director-level down.



*Skills Gaps outstrip Technology Gaps  
(adapted from Srari J.S., Settanni E., and reported in Application of digital technologies to innovation in manufacturing. BSI report 2016)*

If you would like to find out more about our work on digital supply chains, or our wider research framework across global value networks, there are a number of ways you can engage with us, including:

- As a partner in a research collaboration
- By putting our research into practice with our dissemination arm, IfM Education and Consultancy Services (IfM ECS)
- Joining our Digital Supply Chains Consortium
- Attending the annual Cambridge International Manufacturing Symposium

You will find more information about all of these activities at [www.ifm.eng.cam.ac.uk/cim](http://www.ifm.eng.cam.ac.uk/cim)

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To discuss opportunities to embed Centre for International Manufacturing knowledge and expertise within your organisation, please contact:

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# FURTHER READING

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## FORTHCOMING PUBLICATIONS

Lim, S.F.W., and Srai J.S., 'Consumer driven e-commerce: A literature review, design framework and research agenda on Last-Mile Logistics models'.

Hennelly, P., Graham, G., Srai, J.S., 'Do Makerspaces represent scalable production models of community based Distributed Manufacturing?'.

Lim, S., and Srai, J.S., 'Examining the anatomy of last-mile distribution in omni-channel retailing: A supply network configuration and contingency approach'.

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