THE DIGITALISATION OF MANUFACTURING IN JAPAN

Sponsors

On behalf of the Overseas Research Project team, we would like to extend a huge thank you to our sponsors for their generous contributions, without which this project and report would not have been possible.

We would also, similarly, like to thank the following institutions for their generous funding:

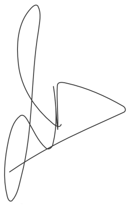
Foreword

The Overseas Research Project is run every year by a group of Masters students at the Institute for Manufacturing (IfM), University of Cambridge, studying the Manufacturing Engineering Tripos. This year we had the unparalleled experience of being able to lead this trip and being able to visit Japan for two weeks, travelling through Tokyo, Mount Fuji and Kyoto, as a group of 23 researchers.

The trip itself was a truly incredible adventure, but so too was the preparation and organisation that led to the realisation of this trip. As a group we learnt to design and carry out useful research, and all the complicated interactions and communications necessary to set up visits to companies. We learnt to seek sponsorship for this research, and we learnt how to budget such a vast project. We learnt to organise a group of 23 individuals, as well as how to plan all the logistics behind travel and accommodation. The organisation certainly had its highs and lows as all large projects, and large teams, must, but the team pulled together to make this at times seemingly impossible dream of visiting Japan come true. Everyone had a part to play, and in doing so everyone can attribute individual learnings to this experience.

Zoscha Partos

When in Japan, we were able to gain a wealth of knowledge surrounding the Digitalisation of Manufacturing, but also surrounding the culture of Japan, a truly awe-inspiring country, as well as furthering our own professionalism in business interactions in foreign countries. From visiting Fanuc, where we were able to see robots building robots at the foothills of Mount Fuji, to visiting the Headquarters of IBM and Hitachi in impressive Tokyo sky rise buildings, to visiting more traditional manufacturers in Kyoto, we were lucky enough to see the breadth of Japanese industry, and meet extremely impressive individuals. This was all alongside wonderful cultural experiences such as a first evening spent wondering at incredible views of Tokyo's skyline, many visits to beautiful temples, attending and partaking in a traditional tea ceremony, and, naturally, enjoying some karaoke. We had an experience that none of us will ever forget.



Jordan Salmon

Overall it was a vast undertaking and, certainly as leaders, we truly believe it has been transformational for both our personal, and professional development. It has been a huge part of both of our lives for the last year and a half and we find ourselves quite emotional to be at the end of this journey. We would like to thank all of the sponsors, companies we visited, and IfM staff involved for their extremely generous contributions: we simply could not have achieved this project without you. We are incredibly grateful for this incredible opportunity to learn so much, have an amazing trip, and produce a piece of research that we are all proud of – we hope you will enjoy it.

Zoscha Partos and Jordan Salmon, ORP Co-Leaders 2016-17

Executive Summary

This Overseas Research Project (ORP) was undertaken by 23 Manufacturing Engineering Masters students during the academic year 2016-17, culminating in a 2-week research trip to Japan in July 2017, organised by the student research group. The project aims to investigate the current state of Digitalisation of Manufacturing in Japan, a multi-faceted theme which is relentlessly found to be at the forefront of manufacturing in today's global industrial environment. Japan has historically led the world with manufacturing initiatives such as Lean, and thus it is important to consider the place that this superpower will play in the future, as the industrial landscape is once again altered, this time by the digital revolution.

The Digitalisation of Manufacturing was investigated by visiting 14 organisations from a variety of sectors, both public and private, and of varying sizes. These visits included site tours of manufacturing facilities, where appropriate, and discussions with key individuals, relevant to the research area of Digitalisation, at the each of companies. This enabled the research to gain insight from a broad range of industrial players in Japan, allowing the group to gain a sense of the general environment for Digitalisation of Manufacturing in the country, with insights from both company and policy viewpoints. Digitalisation of Manufacturing was broken down into the following components for analysis: Research and Development, Manufacturing Operations, Supply Chain, Human Resources, and Digitalisation of Offerings.

Key conclusions found within this research were as follows:

- There was a high level of awareness surrounding Digitalisation of Manufacturing; across the organisations visited there was a strong belief that digitalising was of high importance.
- The human impact of digitalisation was seen to be of the utmost importance, in terms of facilitating digitalisation and the importance of obtaining and saving the necessary skills and knowledge. Additionally, the concept of using digitalisation to aid Japan's issues surrounding their ageing population through increased automation was a recurring theme.
- For digitalisation to succeed, many organisations believed that there needed to be a large increase in collaboration between companies, more open innovation. Additionally, organisations felt there was a need for extensive standards, ecosystems and common platforms that are transferrable across companies. This is a paradigm shift for Japan, where organisations are traditionally more closed.
- Companies that offer digitalised solutions to their customers were found to be far advanced when compared to companies who use digitalisation within internal operations alone. Naturally, companies who offer digital solutions externally invest more heavily in R&D and are pushing the boundaries of digitalisation further.

Edward Holt, Zoscha Partos, Jordan Salmon, and the 20 other researchers of the ORP team, 2017

1 Table of Contents

2 Introduction

This report details the results of the research conducted by manufacturing engineering students (see Appendix B for a list of authors) from the Institute for Manufacturing (IfM), department of engineering, University of Cambridge, during a two-week project to Japan between the 1st and 15th July 2017. The introduction will explain the motivation behind the project, provide a global and national context, and document the initial aims of the research.

2.1 Motivation behind research topic and country choice

During the manufacturing engineering degree at Cambridge, students visit and undertake projects in a wide range of factories throughout the UK. The Overseas Research Project (ORP) aims to broaden this experience by visiting manufacturing facilities in a different country, with a contemporary topic normally chosen as a central theme to investigate throughout the visits.

The digitalisation of manufacturing has emerged as a key contemporary theme in manufacturing around the world in the last decade. Many would even proclaim that the current advances in manufacturing are akin to a 4th industrial revolution [1]. Further information about what this report defines as the digitalisation of manufacturing can be found in section 1.2.

There are conflicting viewpoints in both academia and industry about whether the current progress in manufacturing actually constitutes a revolution. A certain amount of "hype" has been generated, and this has naturally generated an equivalent amount of cynicism. However, it is undeniable that most of the "hottest" topics in manufacturing currently reside around various digitalisation initiatives. As such, the Digitalisation of Manufacturing (DM) was chosen as the main research theme of ORP 2017.

The other crucial choice for the research group of ORP was which country would be investigated. After research into the various national initiatives around the digitalisation of manufacturing (section 1.3), it was established that the main initiatives were being led by the "traditional" manufacturing countries: Germany, USA and Japan. Out of these three nations, Japan seemed the least advanced in applying the technologies and principles of DM[2]. As such, the ORP group decided to undertake an investigation into Japan would be the most salient. This

[1] World Economic Forum (2016), Mastering the Fourth Industrial Revolution, available at http://www3.weforum.org/docs/WEF_AM16_Report.pdf, accessed 25th October 2017.
[2] Ministry of Economy, Trade and Industry (2015), Japanese Factories Connected Together, avalaible at http://www.meti.go.jp/english/publications/pdf/journal2015_05a.pdf, accessed 25th October 2017.

aimed to look into whether policy makers and industrialists felt this apparent lag in uptake of DM was in fact the case, and what in turn they were doing to address this issue.

2.2 Defining the digitalisation of manufacturing

The trend towards digitalisation of manufacturing (DM) first came to real prominence when the German government defined "Industrie 4.0" in 2011 [3]. This definition reasoned that industry was coming to the 4th industrial revolution, a digital revolution. Figure 2-1 shows the evolution of industry through the eyes of the German government.

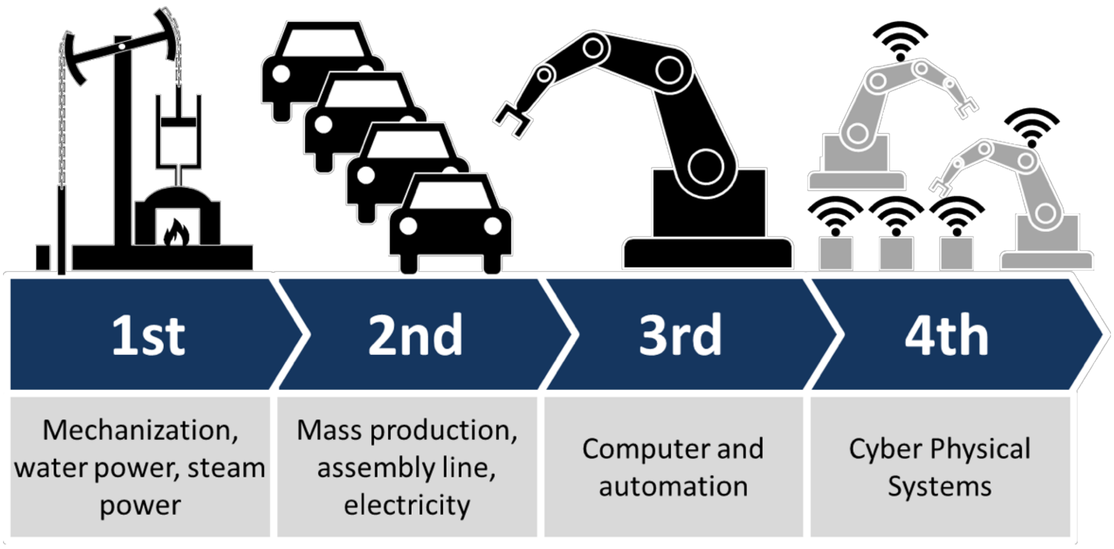


Figure 2-1 - The four industrial revolutions. Source: https://blog.phoenixcontact.com/marketing-sea/wp-content/uploads/sites/14/2017/04/Industry_4.0.png

With Industrie 4.0, the German government aims to "drive digital manufacturing forward by increasing digitisation and the interconnection of products, value chains and business models. It also aims to support research, the networking of industry partners and standardisation. " [4]. The cry of digitalisation has since been taken up by a number of other bodies: national policy makers, consultancies, industrial conglomerates such as General Electric and Siemens. Consultancies have produced reports stating the compelling business need for all manufacturers to digitalise or fail. [5] This has created panic and confusion amongst manufacturers, bombarded by publicity and offers to provide a rather insubstantial digital solution. They are both unsure of what constitutes DM, and also not entirely convinced by the

[3] Federal Ministry for Education and Research (2011), Digital Economy and Society, available at https://www.bmbf.de/de/zukunftsprojekt-industrie-4-0-848.html, accessed 25th October 2017
[4] European Commission (2017), Germany: Industrie 4.0, available at https://ec.europa.eu/growth/tools-databases/dem/monitor/sites/default/files/DTM_Industrie%204.0.pdf, accessed 28th October 2017
[5] PwC (2016), Industry 4.0: Building the digital enterprise, available at https://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf, accessed 28th October 2017.

compelling business need for it, leading some to brand DM as just hype[6].

To try and avoid this confusion when investigating DM in Japan, ORP looked to define both the facilitating technologies behind DM, and the business need driving adoption.

Undoubtedly, the digital manufacturing revolution has been facilitated by technology. A common misconception is that all of this technology is brand new – that is not the case. The Industrial Internet of Things (IIoT) has been around for more than 20 years, for example. [7]However, the reduction in cost of the various technologies involved in DM has now brought them into the realms of the majority of manufacturers, enabling more of a true revolution. Three broad categories of enabling technologies were found to exist:

Internet of Things (IoT): IoT involves connecting any device with an on/off switch to the internet, in order to drive data collection, autonomous action and consumer insights[8]. IoT in a DM context looks at the increased use of sensors throughout all areas of production, which has been an ongoing trend for the past twenty years. The newer concept is the consumer IoT, which has huge implications for factories of the future. Real time consumer data can be gathered from products in use, enabling early quality incident investigation, adjustment of production parameters and more accurate forecasting and production scheduling.

Big Data: Big data is defined by 4Vs: Volume, Velocity, Variety and Veracity, as can be seen in Figure 2-2.

Manufacturers are no strangers to having vast amounts of data on their production system. However, there is a consensus that there is a gross under-utilisation of the data collected. The trend in big data and artificial intelligence (AI) enables autonomous analysis and presentation of this data for easier use.

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[6] IEEE Industrial Electronics Magazine (2014), Industrie 4.0: Hit or hype?, available at http://www.control.lth.se/media/Education/EngineeringProgram/FRTN20/2016/docslide.us_industrie-40-hit-or-hype-2.pdf, accessed 28th October 2017.

[7] McFarlane, D & Brintrup, A (2016), Getting smart with digital, available at https://www.ifm.eng.cam.ac.uk/news/getting-smart-with-digital/, accessed 2nd November 2017.

[8] Morgan, J (2014), A simple explanation of the Internet of Things, available at https://www.forbes.com/sites/jacobmorgan/2014/05/13/simple-explanation-internet-things-that-anyone-can-understand/#28c9000b1d09, accessed 28th October 2017.

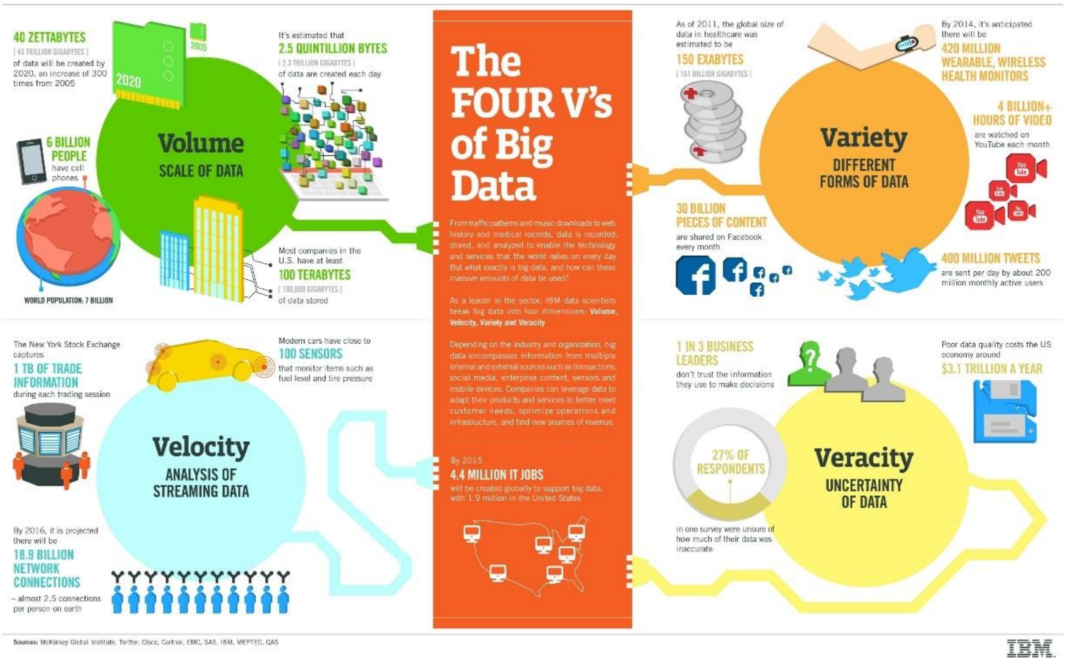

Figure 2-2 The four Vs of Big Data (Source: http://www.ibmbigdatahub.com/sites/default/files/infographic_file/4-Vs-of-big-data.jpg)

Cyber-Physical systems: When most people think of "progress" in manufacturing, they think of automation and the elimination of humans from the process. However, cyber-physical systems involve the deeper integration of worker and the digital world[9]. There are a number of key enabling technologies in this category, including: collaborative robots which can work side by side with humans, augmented reality to allow easier interaction between physical and digital systems.

Understanding the enabling technologies is an important element of DM, but just as important is understanding the perceived business need behind applying these. Frequently it is found that the problem with digital manufacturing is that companies understand what technologies can be applied, but do not understand how they can improve an aspect of their operations. Again, three main categories emerged demonstrating where in particular DM can improve the operations of a manufacturer:

Improved productivity: Doing more with less has always been the goal of manufacturing. Companies are using DM to do this, just as they did with automation beforehand, and with steam power before that. There are many different ways in which DM can improve productivity, such as further reduction in effort from increased human-robot collaboration, better root causing of chronic losses through more effective use of data, or leveraging global assets more effectively through digital systems.

[9] NIST (2017), Cyber-physical systems, available at https://www.nist.gov/el/cyber-physical-systems, accessed on 28th October 2017.

Increased sustainability: DM has a focus on end to end supply, from design to consumer. This can help to eliminate waste at every stage of the production process and increase sustainability, a key goal for many manufacturers.

Increased resilience: Dealing with uncertainties in materials and "shocks to the system" is a key way for manufacturers to remain competitive[10]. Through DM, companies have the power to better anticipate and mitigate such shocks to the system, and, with more of a focus on digital rather than physical assets, have the power to react more effectively after such a shock than previously possible.

2.3 Global context

In terms of the global context surrounding the digitalisation of manufacturing, there are two main streams to look at: policy maker led initiatives, and the response from industry.

As previously explored, the drive for DM began with policy makers in Germany declaring the 4th industrial revolution. Germany's focus on DM stems from their manufacturing sectors strength in SMEs, or the "Mittesland" as it is more commonly known. The Mittesland make up 52% of Germany's economic output[11]. SMEs have been identified as the most at risk of being left behind by DM[12], and so by generating conversation and some degree of hype, the German government can hope to engage and support their important sector.

It did not take the USA long to follow the German government in pushing their manufacturers towards DM. President Barak Obama commented on this in his state of the union address[13]. While the German focus is primarily on IoT, American policy is to play to their considerable current strengths in the big data sector and leverage this category for manufacturing.

Closer to home, UK policy makers have also been busy playing catch-up with their German and American counterparts. As part of the new government industrial strategy, a digital manufacturing working group was established under Jurgen Maier to assess how UK manufacturers could be supported with the transition to digital. While the group has only just released their report, it is clear that the UK has the same

[10] Sheffi. Y (2007), The Resilient Enterprise, MIT Press
[11] Federal Ministry of Economics and Technology (2011), The Mittesland, available at https://www.deginvest.de/DEG-Documents-in-English/About-DEG/Events-and-Awards/BMWi_Study_German-Mittelstand.pdf, accessed 2nd November 2017.
[12] Schroder. C (2017), The Challenges of Industry 4.0 for small and medium sized enterprises, available at https://www.deginvest.de/DEG-Documents-in-English/About-DEG/Events-and-Awards/BMWi_Study_German-Mittelstand.pdf, accessed 2nd November 2017.
[13] The White House (2014), President Obama…, available at https://obamawhitehouse.archives.gov/the-press-office/2014/02/25/president-obama-announces-two-new-public-private-manufacturing-innovatio, accessed 2nd November 2017.

impetus to implement DM as other countries, particularly considering the challenges ahead due to exiting the European Union.[14]

On the industrial side, it is clear that the multinational companies are leading the charge for DM, supported by a wealth of start-ups capitalising on the new skill set and mindset that DM can often require. In terms of cross-nation DM, two industrial conglemerates are omnipresent: Siemens of Germany and General Electric (GE) of the USA[15].

2.4 Industry in Japan

In the 1980s, the world was in awe of Japanese manufacturing. The Toyota production system masterminded by Taiichi Ohno, and the concepts around lean manufacturing were still a mystery to Western manufacturers, who puzzled over the massive productivity advantages that Japanese companies enjoyed. This was particularly true in the automotive industry, as detailed in "The Machine that Changed the World"[16].

However, the "secrets" of lean manufacturing were soon distributed and adopted throughout the world, and the Japanese hit a productivity plateau[17]. The country dropped from 2nd or 3rd in productivity rankings in the world during the 1990s-2000s to 14th in 2005 and have stabilised since at around 11th[18]. For a nation used to leading the world, this was a bitter blow.

As such, the question is postulated that with the world of manufacturing once again in flux, can Japan regain such an enviable initiative with DM, or will it become a bystander on manufacturing innovation? This is discussed throughout the report, with a particular focus on policy makers in section 8.

2.5 Research methodology

When selecting companies and organisations to visit during our research, the project aimed to visit a broad range in order to get an overview of DM in Japan. This meant contacting a variety of companies, small and large, in diverse sectors, as well as policy makers and academic organisations. A summary of the companies investigated can be found in section 2.6.

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[14] Maier, J (2017), Why Britain must lead the fourth industrial revolution, available at http://juergenmaier.co.uk/why-britain-must-lead-the-fourth-industrial-revolution/, accessed 2nd November 2017.

[15] The Economist (2016), Siemens and General Electric gear up for the Internet of Things, available at https://www.economist.com/news/business/21711079-american-industrial-giant-sprinting-towards-its-goal-german-firm-taking-more, accessed 2nd November 2017.

[16] Womak. J (2007), The Machine that changed the world, Simon and Schuster UK.

[17] Smith. N (2015), Japan's productivity problem, available at https://www.bloomberg.com/view/articles/2015-06-29/japan-s-productivity-puzzle, accessed 2nd November 2017.

[18] 2017 METI white paper on digitalisation, shared with the group during visit July 2017, not yet published in English

In order to split the research between the group of 27 people, it was decided that DM would be investigated through different lenses representing various sections of the value chain. These were chosen as follows: R&D, supply chain, manufacturing operations, human resources and digitalization of offerings. A separate section analysing the actions of policy makers in Japan was also viewed to be of value.

In each section the three main technology themes of DM, as discussed in section 2.3, would be analysed, as well as the business need behind applying them. Pre-research was done in February 2017, including extensive reading and generation of specific questions for each company. These were then addressed in advance by email and also during the visits themselves.

2.6 Company summaries

14 organisations from a variety of sectors, both public and private, of varying sizes, were visited. A brief summary of each of the companies visited can be found in Appendix A.

3 Research and development

Research and development (R&D), is key to the development of digitalised systems, products and operations in manufacturing. Due to the yet undeveloped and early stage of the digitalised manufacturing systems life cycle, R&D is the key to the progression of manufacturing in Japan. Many firms have turned to R&D both internally and externally to remain competitive and to develop their core competencies and business models. Digitalised systems are on the whole still underdeveloped around the globe and in Japan. Even leading countries such as Germany have not yet fully developed their own Industrie 4.0 initiative. For this reason, R&D is the underlying force required to develop these systems. R&D is crucial to the advancement of immature technologies, and as such is the crux of many companies' approach. Both the public and private sector have identified this, and Japanese firms appear to be separable into three categories when it comes to their approaches to this new challenge. The three approaches are as follows:

1. **Traditional**: Firms which, whether consciously or not, have taken a stance of avoiding the digitalisation of industry. The systemic reasons for doing so emerges from the nature of the firms' offerings. These would be such that digitalised R&D appears not be useful, in large part as their operations and products gain significant value from their traditional manufacturing processes and heritage. In other cases, the gap between new digital technologies and traditional technologies already in use make the investment required for this R&D prohibitive.

2. **Adopters**: Firms which have begun to adopt digitalised systems and operations. These firms will often use digitalisation techniques such as Big Data analysis and IoT. In order to support these functions, they have begun to undertake some R&D in digitalisation, often forming partnerships with other firms and undergoing Open Innovation.

3. **Enablers**: Firms at the forefront of R&D for digitalisation can be considered enablers. The value proposition of these firms is to enable the adoption of digitalised techniques for other firms, through knowledge sharing or the creation of enabling products. These firms are at the forefront of the development of digitalised systems.

The difference between these three approaches to R&D in the context of digitalised manufacturing is included in Table 3-1 below.

	Big Data	IoT	Cyber-physical systems
Traditional	Some use of Big Data to optimise their systems, however, usually traditional manufacturing methods lead to a lack of data and of software competency	Not applicable, traditional methods tend to make integration of sensors and internet connections undesirable	Not applicable, traditional methods tend to make integration of sensors and networked systems undesirable
Adopters	Big Data is key to the development of efficient and competitive manufacturing techniques for adopters, hence much R&D spending in this area	IoT is key to the development of efficient and competitive manufacturing techniques for adopters, hence much R&D spending in this area	Cyber-physical systems have been found to be less common, as IoT systems provide more value, however, adopters are likely to commence R&D in this area
Enablers	Big Data is key to the development of efficient and competitive manufacturing techniques, many enablers aid other firms in using their own Big Data	Enablers often develop IoT systems sometimes finding novel ways of connecting machinery and capturing data, doing a lot of R&D	Enablers often develop IoT systems, but due to a servitised selling mechanism may not adopt these systems themselves

Table 3-1 : Digitalisation comparison for R&D of Japanese firms

The visited firms have been split according to their positions within these three criteria illustrated in Table 3-2 below.

Traditional	Adopter	Enabler
Hori - Gold leaf manufacturer	Vpec	IBM
	Fanuc	Hitachi
Tukino Katsura - Sake brewery	Kyocera	Preferred Networks
	Daikin	
	ATR	Hilltop
		KIT

Table 3-2 : Classification of companies visited

From these three perspectives, the approaches to R&D in the digitalisation of industry can be analysed. During the research trip, multiple trends have been identified showing how behaviour towards R&D differs between the three types of companies identified. These will all be discussed in this section.

3.1 Servitisation

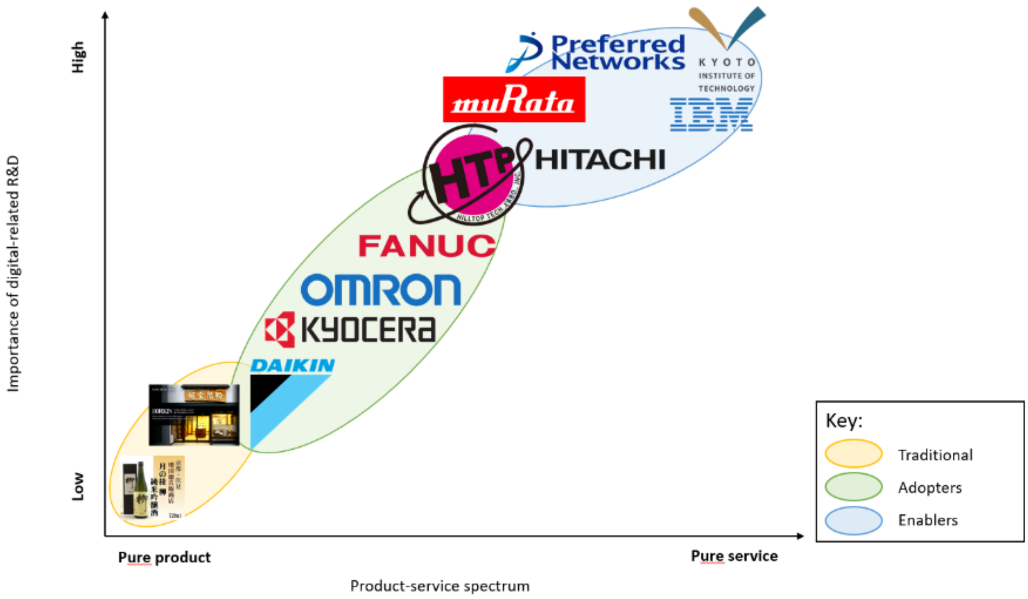
Recently, many firms, such as IBM, have shifted their offerings from products to product-service system. A product-service system is an integrated product and service offering in order to optimise mutual value provided. In the case of IBM they have shifted from selling computers to providing tools and solutions for a cognitive supply chain. According to research there are five types of product-service systems and hence five ways to servitise:[19]

1. Integration oriented PSS: the customer maintains ownership of the product, but the supplier seeks vertical integration in order to provide associated services
2. Product oriented PSS: the customer maintains ownership of the product, but additional services directly related to the product are provided
3. Service oriented PSS: the customer maintains ownership of the product, but additional services are offered as an integral part of the value offering
4. Use oriented PSS: ownership of product is kept by service provider who sells the function of the product via modified distribution and payment systems
5. Result oriented PSS: replacing the product with a service

[19] "The Servitisation of Manufacturing: an Analysis of Global Trends" by A. Neely, (https://cambridgeservicealliance.eng.cam.ac.uk/resources/Downloads/berlinserviceskeynote.pdf , accessed 12th December 2017)

As a result, it can be difficult to differentiate between whether an offering is a product or a service. In reality, the offerings from companies will range on a spectrum from pure products to pure services with the five PSSs in between.

During the time spent in Japan, a trend was identified between the importance given to R&D into digitalisation and where a company was positioned on the product-service spectrum. Graph 3-1 below shows the positions of all the companies visited. Note that ATR is not included since they provide neither products nor services.



Graph 3-1: product-service spectrum vs importance of R&D

As can be seen, traditional companies (shown in yellow) mainly offer pure products and gave essentially no importance to digital R&D. A good example of this is Tukino Katsura which offers a pure product (bottled sake) and has no R&D into digital as they wish to maintain traditional methods and thus have little interest in digitalisation. Havig said this larger sake firms have tried to understand this traditional process chemically, one of the employees of Tukino Katsura worked for a larger firm who spent a lot of resources monitoring and sensing these traditional methods. Meanwhile, adopters (shown in green) usually had offerings in the middle of the product-service spectrum and gave medium importance to R&D. An example of this is OMRON who manufacture PCBs (for manufacturing control systems) but also offer solutions to help customers automate their manufacturing processes using sensors and their control systems. Finally, enablers (shown in blue) had service heavy offerings and gave high importance to R&D. Preferred Networks illustrate this very well, offering digital solutions to clients as a service whilst giving high importance on R&D as it is one of their core competencies.

CASE STUDY

ATR

ATR was a particularly interesting case when it came to R&D. ATR does not provide a product or a service. Instead they focus purely on conducting R&D into information and communication-related areas. Meanwhile, ATR promotions - a subsidiary and part of the ATR group, but still separate to ATR itself - helps commercialise the technologies and ideas developed by R&D. As such, ATR only focuses on developing new technologies and discovering breakthroughs in the information and communication-related areas. By not being preoccupied with making a profit form their ideas, ATR can instead focus on conducting the research they truly think will provide the most social value and can act more freely. Firms like ATR, or Fraunhofer Institutes which are the German equivalent, which focus purely on R&D and do not necessarily commercialise ideas themselves are essential for the development of ideas and breakthroughs in digitalisation-related technologies. However, they can only conduct useful research if they receive enough funding, even if the funding does not necessarily lead to them largest possible profits. As a result, some goodwill is required for the success of ATR and similarly run companies.

This suggest that the amount of R&D related to digitalisation conducted by firms will depend on the form of their value offerings. As a result, it seems likely that the main breakthroughs and advancements in digitalisation are going to come from companies who are on the service side of the product-service spectrum, as they are placing much higher importance on digital-related R&D. Therefore, companies offering services in the digital area are likely to be key for the future of digitalisation in Japan.

There were two notable exceptions to the pattern identified. The first exception is KIT. Amongst many others, one of the areas of research conducted in KIT related to traditional Japanese "manufacturing". Two examples of traditional "manufacturing" they explored were traditional weaving, "Kara-ami", and clay plastering. KIT used digital methods to capture best practices for these traditional areas. By capturing the best practice, the methods used in these traditional areas could be preserved and potentially can be used for training in the future. This involved gathering large amounts of motion data to digitalise these traditional skills to help train others. For example this showed that the steepness of someone's shoulder-line while plastering was key to the quality although this was not conveyed my any of the experts while training others. Whilst, KIT was not itself a traditional company, it did allow traditional companies to use R&D into digitalisation to help improve and preserve their techniques.

The second main exception is Hilltop. Hilltop's revenue stream comes from making low-volume, rapid prototypes on CNCs, a product-oriented PSS. However, employees are given freedom to research any areas or ideas they wish to explore. Some examples of project that employees have undertaken included developing autonomous vehicles and helping team Japan build a rover to go to the moon. Hilltop will not necessarily commercialise all these projects, so they are not essential for the company's survival. However, as part of the company culture, employees are still encouraged to do as much of this R&D as possible they still conduct research which can lead to insights in the area of digitalisation. Because of this they are moving towards more service orientated offerings with their future strategy being a fully service orientated. Using their learnings from their current business to drive this R&D, one of their goals being to create a software package that automatically writes CAM for CAD.

3.2 Incremental vs. radical change

The digitalisation of manufacturing has been identified by many institutions and bodies as a radical change – even to the extent of being termed a fourth Industrial Revolution. The four revolutions in manufacturing are broadly identified as:

1. Mechanization, water power, steam power
2. Mass production, assembly line, electricity

3. Computer and automation
4. Cyber physical systems and the digitalisation of manufacturing

The initial three revolutions have been observed and well documented in academia and industry alike. The fourth is as of yet not fully realised and still involves some speculation, especially considering it is the first one to be named before it has happened.

Research suggests that there are two types of innovation[20]:

- **Incremental innovation** improves performance relative to the current customer criteria
- **Radical innovation** presents a completely new value offering. It may initially perform lower than the current technology but offers the potential to outperform the incumbent in future

These two types of innovation correlate directly to the two types of technology which they can discover. These are sustaining and disruptive technologies[21]:

- **Sustaining technologies** improve performance of existing products with reference to current customers' performance measures
- **Disruptive technologies**' product performance may be initially worse but presents new value proposition

It has been observed that this digital "revolution" may actually consist of multiple incremental innovations rather than a radical one, and as such is not truly the fourth industrial revolution. These incremental innovations have led to sustaining technologies rather than disruptive technologies.

While the previous three revolutions have changed the fundamental methods of manufacturing and often developed entirely new organisational structures, skills and technologies, this revolution is more of a sustained development of the current technologies. This idea was touched upon by Daikin, whose manufacturing managers reasoned that the current development in manufacturing is more of a continual incremental innovation. This was evident in Daikin's AGVs and predictive maintenance, which is being developed, one improvement at a time, making better use of existing technologies with every version. The AGVs had slowly been developed via incremental changes to their in-house transportation systems, and their predictive maintenance, which was not a new and unprecedented use of data, but more of a

CASE STUDY
OMRON

Omron develop eco-friendly clean rooms by adjusting the level of fanning contingent on the accumulated dust on their production line. This allows Omron to reduce their fanning and therefore electricity use when the dust levels are already low. Additionally, Omron set up clean rooms on shelves with plastic sheeting instead of using fully fledged rooms dedicated to this purpose. These innovations have come to light through the development of existing technologies. Their use of shelves with plastic sheeting is an example of innovation at the parts level. This is not a radical change, but an incremental change enabled by the development of better fanning systems. Further, the use of eco-friendly fanning comes from the ability to use previous data and small weight sensors. Both of these developments stem from digitalisation – IoT and Big Data. However, they are just major cost/efficiency gains borne out of incremental technology developments, not major technological jumps. In this way, Omron show that R&D does not need to be revolutionised to achieve digitalisation.

Omron look into changing their products by using some of the machine data to better develop smart machines. This is not a radical change, Omron have always studied the ability of their products to work more efficiently by using their own data, however, their ability to use data has increased with the development of sensors and better data analysis techniques. This incremental change to their R&D in their products is impressive but, again, not necessarily revolutionary.

[20] Evolution of industries, technologies and markets, lecture at University of Cambridge Institute for Manufacturing, T. Minshall, 23rd January 2017.
[21] As previous reference.

slow development of old methodologies allowed by increasing the volumes of data and advancing the methods used to record and analyse such data.

This ties in directly with the changes observed in industries which have a dominant design, rather than industries developing new platforms. Mature industries tend to display the following trends[22]:

- Modularisation
    - Specialist parts suppliers
    - Innovation at the parts level
    - Major cost/efficiency gains
- Complementary assets dominate
    - Manufacturing
    - Brand image
    - Market knowledge
    - Distribution

Leading enablers, such as IBM, have all of the aforementioned complementary assets. This suggests that industry is not undergoing a change to the dominant methodologies of manufacturing but a sustained development of current technologies. The implications of this for R&D are that digitalisation will not be developed by large jumps in R&D aimed at "blue sky" ideas, but rather, further development of current R&D in efficiency gains via computing and sensors. Many firms may already be undergoing R&D in the use of technology and digitalised systems, and, rather than searching for new trends in this sector, they should aim their efforts and funding at continuing current R&D practices which will lead to modularisation.

It could be hypothesized that the digitalisation of manufacturing is a furthering of current technologies such as miniaturised sensors and data crunching as opposed to a new industrial revolution which is changing the fundamental performance of industry via large changes to the organisational structures, skills and technologies. This has a significant impact on the nature of R&D carried out in this area by firms. Rather than using R&D to look for brand new, radical technologies that could immediately change the manufacturing world, firms may be better off using R&D to improve the current technologies. For example, making sensors even smaller and cheaper, increasing data processing speed and improving ways of visualising data, are just some of the ways firms can improve existing technologies and still achieve a huge impact on their operations.

3.3 Collaboration

A notable trend in the R&D strategies of the researched companies was the significant emphasis on collaborative development

[22] As previous reference.

and open innovation. Among the manufacturers interested in digitalising their operations ('adopters'), there was a frequent perception of a deficit in the skills required for digitalisation, particularly those required for complex cloud-based data analytics and data interfacing between sensors and the cloud (see section 6). Meanwhile, for the 'enablers', companies developing offerings which promote this digitalisation, there is an apparent need to leverage their internal expertise in this area to help 'adopters' overcome this knowledge barrier and make use of the enabler's offerings. This complementary demand and supply of expertise lead to multiple adopter-enabler research partnerships, beyond simple business transactions. The partnership of Preferred Networks (PFN), a deep-learning start-up, and FANUC, the manufacturer of FA systems, is a case-example of one such partnership, which also demonstrates how the transfer of expertise and resources is not a simple one-way exchange.

The prevalence of collaborative projects in the companies surveyed is striking when the material is reviewed: Of the enablers and adopters identified, only Kyocera did not mention a specific example of a partner for collaboration in digitalisation. However, the visit was hosted by the recently appointed Head of Open Innovation who spoke of the need to digitalise, implying an intended shift to significantly more open research in the area. That Murata, a company previously famed for its closed, internal approach to R&D, presented to the trip, from their recently-opened Open Innovation Centre, Murata's plans to transform its attitude of the stereotypically inward-looking Japanese corporation.

It is important to make the distinction between efforts being made towards collaborative R&D in this area and those being made towards fully open innovation. Whilst the former offers a potentially more conservative and controllable route to fulfilling the resource requirements of short-term digitalisation in the form of process improvement (such as Omron's partnership with GM to optimise their production line for Zero Down Time), open innovation may hold the key to identifying the truly transformational changes to value offerings and business models which hold the full value of digitalisation in manufacturing. Though there are some increased risks in intellectual property protection for more open approaches to research, there are various factors that can mitigate the risk of OI in the digitalisation of manufacturing:

- Companies are able to design their interactions to protect their IP in collaborative relationships. Both Daikin and IBM emphasised their development and promotion of APIs, in order to facilitate 3rd party development relationships whilst also controlling access to their data using a standardized access point. The development of Open Innovation centres at Murata, Kyocera & Daikin (in the form of the Technology and Innovation Centre) also

CASE STUDY

FANUC & Preferred Networks

The partnership of FANUC and Preferred networks provides a case-example of a partnership between an adopter and an enabler in order to supply the former with the technology and the expertise required to digitalise. In this case, the technology is the deep learning expertise of PFN , applied to provide distributed reinforcement learning (an edge-heavy form of machine learning) for FANUC's Factory Automation robots. An example application given was for a FANUC bin-picking robot, initially selecting points at random to attempt to pick up cylindrical parts – after 8 hours of autonomous reinforcement learning (assigning values to positive and negative outcomes and optimising the picking algorithm to maximise the value the outcome) the robot could operate at a performance level as good as (or better than) that taught by a manual teach process.

For Fanuc, the benefit here is clear – however the benefit to the enabler, PFN, goes beyond the simple benefit of a customer for its services. As a company working at the forefront of deep learning, it is attempting to compete in a field dominated by multi-national technology giants with vast repositories of data at their disposal on which to conduct research and train their learning algorithms – Facebook, Google, Amazon. By specialising its deep learning to fulfil the needs of manufacturing, automotive and biotech firms it not only selects a niche to work in separate to the activities of the incumbent giants, but also gains access to a source of big data with which to train its own algorithms. In a field in which each business project is also a new and unique research opportunity, this is crucial to its very existence as a business.

The enabler-adopter relationship is evidently much more complex than meets the eye.

provides a means to control this risk by channelling information flow through a specific gateway. Murata in particular spoke of the need to prepare their intellectual property for digitalisation, i.e. to analyse which technologies were fully confidential, which should be made open-source and which might be partially disclosed over the course of a longer-term relationship.

- As noted by Preferred Networks, given the very application-specific nature of digitalisation technologies – such as their work on machine learning in manufacturing - there is a lower risk of working with multiple companies within the area of digitalisation (at present). The knowledge exposed within each partnership is difficult to transfer to other applications without the accrued expertise of PFN (or equivalent enabler), whilst the technology implemented is bespoke to one application (e.g. pick and place machine learning). Their confidence in this extends to the point of developing Chainer, an open source framework to support deep learning research, in order to encourage others to develop new applications of deep learning which PFN might be able to utilise. However, with the future development of digitalisation platforms (the ultimate goal of IBM and PFN), the risk of unwanted technology transfer beyond the original application may increase as applications become standardised.
- There may also be an argument that the cultural alignment of different Japanese companies within their respective niches may help to promote collaboration in this field. When questioned on the potential threat of domestic competitors 'piggy-backing' on the learnings gained from the digitalisation of companies operations, an ethic of collaboration for the common good was frequently articulated by the companies visited, stating that they viewed Japanese competitors as partners each with their own niche and purpose - rather than threats.

A final trend noted regarding the observed approaches to collaboration was the emphasis on physical demonstration of development work to potential customers. This generally took two forms: purpose-built examples of IoT applications, as exemplified by Murata and IBM, intended to generate future business for the company in related digitalisation projects; or demonstration of the company's products using its own manufacturing operations as a showroom. For the latter, both Omron and Fanuc are prime examples, as they use their own products within their factories. This has the dual benefit of allowing them to showcase their products in action in their own factories, whilst also allowing them to improve their offerings with the learnings gained from being both an end-user as well as a manufacturer of their product. As further evidence of this, Hilltop are also intending to use their own operations as a test-bed and showcase for their all-in-one sensor development, before offering them for use by SMEs in digitalisation of their manufacturing. This use of the factory as a showcase is particularly notable given the apparent lack of similar approaches in the UK (observed over the course of industrial visits the Manufacturing Engineering Tripos course), which might be a valuable learning point.

3.4 Conclusions

The research trip has led to the making of four conclusions regarding digital related R&D:

1. Companies can be split into three categories relating to their approach to digital-related R&D: traditional; enabler; adopter.
2. Those companies that focus on providing offerings on the service side of the product-service spectrum give higher importance to digital-related R&D and as a result are more likely to make significant developments and breakthroughs in this area.
3. Digitalisation may not be a fourth revolution, as marketed by many, and may instead be an improvement of the use of existing technologies. Therefore, the R&D conducted should not just focus on radical innovations but instead should also focus on incremental innovations of their current digitalised systems.
4. Due to a lack of all the necessary skills within any single company, collaboration between firms is essential for optimising R&D. Open innovation will play an important role in the development of fully digitalised firms.

Overall, R&D will play an essential role in allowing digitalisation of manufacturing. Firms with an incentive to digitalise should focus on collaboration and the pooling of resources to allow for efficient and competitive R&D. Further, servitised firms will be the leaders in R&D of digitalised systems, so should be sought out as experts in R&D in this area. Finally, digitalisation is already happening, and firms should continue their push for incremental innovations in this area. Due to the early stages of digitalisation, R&D will be the source of the future of this progression in manufacturing.

4 Manufacturing Operations

In this section, the operations of the visited companies are compared in the three distinct sections of digitalisation identified in section 2.2. Many of the firms visited do not perform any in-house manufacturing and instead aid the spread of digitalisation via collaboration with other businesses. This section of the report only deals with findings which directly relate to the internal operations of the companies, not to how they aid the performance of other organisations, which is covered in section 7.

All companies which are embracing digitalisation are doing so for a combination of reasons, which are explained as follows. Digitalisation allows a higher level of resilience to shocks or changes in the system by aiding prediction of high impact events and greater security due to network storage. It also increases productivity by highlighting, using collected data, areas of the organisation which are underperforming and allowing improvement processes to be targeted. Finally, it can increase sustainability of the operational context of the organisation by allowing more information flow through the system. This means inefficiencies such as overproduction and waste are minimised.

4.1 Internet of Things

Drawing on knowledge gained during the research project, it is evident that different Japanese companies have embraced the Internet of Things (IoT) within their manufacturing operations to varying degrees. At FANUC, each robot contains many sensors which are permanently monitoring the robot's status. One example of this is a sensor which monitors a bearing in an anthropomorphic arm. If the sensor indicates that it is going to fail, then a warning message appears and the bearing can be replaced. This is part of FANUC's "zero down time" initiative[23] which aims to always have the production line running. This means that the productivity of the system is massively increased due to reduction of downtime, and the resilience of the system is improved due to the ability to perform predictive maintenance. This is something FANUC are looking to add to their value offerings by analysing their robots' data after it is sold to customers, adding an additional service element to their robots. They have tried it out in their own factories to prove its worth to new and existing customers, see more in section 7.2. OMRON have similar systems running within their factory, trying to use their own controllers to predict the breakdown of the machine they are controlling. Again, they are testing their own new systems in their own factories.

In contrast, the traditional Tukino Katsura sake brewery contained no evidence of the Internet of Things. Human intuition and years of

CASE STUDY

FANUC

FANUC is the top producer of industrial robots in the world and calls itself "the automation company". Their headquarters are located at the base of Mount Fuji and consist of 25 factories. These factories include fully automated lights-out production facilities as well as rigorous testing areas. The majority of the production is completed by FANUC-made robots and machines which means that the entire production line can be considered as a testing line for their products. This also includes their interactions with machines made by their clients such as MAZAK. Furthermore, their production lines are used to promote their automation services, therefore tours are regularly given to potential clients, however much of the site remains quite secretive. They certainly demonstrate highly advanced operational capability with the little they let the group glimpse at.

[23] *Zero Down Time*, Tom Green, October 2016 - https://www.roboticsbusinessreview.com/manufacturing/zero-time-fanuc-explains-robobusiness/ , accessed July 2017.

training were relied upon to create the sake, rather than electronic sensor systems. One member of staff had previously worked at a more automated brewery and explained that the automation made for worse quality of taste as the machines can't taste the sake. Furthermore, in this case even if the IoT could be used to automate high quality sake production, potential customers would not value it in the same way as its unique selling point is the fact that it is handmade. So improvements to productivity, sustainability and resilience can be sacrificed. Many people are drawn to the products of this brewery because of the culture and history behind it. It must therefore be remembered that although the IoT is a great technological revolution, it is not suited to every industry or business.

Despite this, research which was presented at KIT (Kyoto Institute of Technology) aimed to digitally record the movements of master craftsmen in various disciplines, such as traditional bow making. There is the possibility that this data will be used to train robots in the future to perform these tasks with the same skill as a human and increased productivity offered by automation. However, their initial aim was to use it as a way to capture these craftsmen's knowledge, so it will not be lost as Japans population ages. Many of these arts are formed through practice and are not easy to explain using words. For example, their tracking software found more skilled traditional Japanese plasterers curved their back in a unique way, something they didn't necessarily noticed they were doing but seemed to be the main difference between one and ten years of experience.

The IoT is seen by many Japanese companies as a platform to accelerate innovation within partner companies. A good example of this is Preferred Networks, because their deep learning programme Chainer has been made freely available[25]. This allows the sharing of solutions and encourages collaborations between companies. This collaboration means that the rate of improvement within manufacturing operations is increased across all companies involved. FANUC, whilst being a vastly different company, have taken a similar approach by producing an open source platform for their machines[26]. This allows developers to create applications to connect their products to FANUC's machines. The use of the Cloud and the internet has enabled more flexible collaboration as each machine simply requires an internet connection, rather than complex custom connections.

All of the Japanese companies visited are looking to the future and planning to improve their manufacturing operations further. However, their approaches are varied. A visit to OMRON revealed how they use the Internet of Things to improve their manufacturing operations.

CASE STUDY
OMRON

The OMRON Kusatsu plant manufactures and sells PLCs, which remain one of OMRON's flagship products. In the factory, a range of automated and manual processes are exhibited to achieve flexible production. Machines are only used when humans cannot perform the task in a satisfactory way. For example, surface mount technology (SMT) printers were fully automated whilst housing assembly was a fully manual process. Through-hole breadboard assembly is an example of both automated and human methods interacting to achieve the required output in a complex and variable task. Data from all automated systems is displayed in a graphical manner throughout the factory on interactive viewing boards, however, this means that human decisions are needed to respond to the data rather than machine autonomy.

[25] *Preferred Networks Release Version 2 of Chainer*, Preferred Networks, June 2017 - https://www.preferred-networks.jp/en/news/pr220170602 , accessed July 2017
[26] *FANUC Develops New Software Platform for Industrial Robots*, BI Intelligence, April 2016 - http://www.businessinsider.com/fanuc-develops-new-software-platform-for-industrial-robots-2016-4 , accessed July 2017

Certain production lines are replicated across global facilities and they all have embedded sensors recording how the lines are performing. Comparing the results allows improvements to be made when a certain line is falling behind, increasing productivity. This is especially impressive when compared to a large U.K. car manufacture. Here they were unable to draw comparisons between two identical lines in the same factory. Therefore, it is very impressive that OMRON are able to compare and improve lines across the world. DAIKIN have taken an alternative approach. Efficiency is their sole focus and data collection is secondary, and in some places ignored. This is exemplified by the numerous custom built production systems which fill the factory. These are unique to their Shiga factory and so global comparisons are not possible. Therefore, many of these systems do not contain sensors but instead rely on operators to recognise issues. While this is increasing productivity in the present, it may be detrimental in the future for resilience when issues cannot be predicted.

This concept of using IoT devices and small sensors to be able to visualise entire factories live and online was seen as key to digitalising operations. It was a priority seen in many of the factories we visited, with DAIKIN's aim to be able to see the performance of all their sites live in a control room. OMRON equally wanted to take their own success in this further to more areas of their operations.

Some Japanese firms feel that they would like to expand into IoT systems but that the complexities of their business is holding them back. Between the two extremes of the traditional Sake brewery and highly digitalised firms like Fanuc, it was found that Kyocera was a firm in the early stages of embracing the Internet of Things. To date they have automated select functions in their production process such as weighing and loading, and they are focusing on optimising CAD/CAM systems in order to improve their rate of response to customer requests. However, they felt constrained and "behind on digitalisation" due to the huge amount of variation in materials and processes. Knowing how to sense certain parameters was perceived as the primary obstacle to moving onto mainstays of digitalisation such as AI and the Cloud. It was unclear whether Kyocera was truly being held back or whether there was just a lot of work to do at this specific stage of development. Other visits indicated that collaboration with the right partners could allow Kyocera to overcome these obstacles, such as using Hitachi's offerings to cope with production complexity and Omron's products to introduce sensory capabilities.

4.2 Big Data

A key finding of the research trip is that every company visited does or is intending to collect and analyse data about every part of the organisation. As found by the group's visit to METI, 26% more data is being collected within manufacturing operations in Japan, the problem being that they don't know what to do with it. For example, IBM collects data from the 170 countries in which they operate and their 400,000 employees[27]. Furthermore, the 25 factories in the FANUC headquarters all simultaneously share data[28].

This data is often used to aid an emerging trend called 'global production'. Global production is a Japanese notion in which quality of products is uniform throughout different factories and production only occurs in the optimum location to enhance productivity[29]. This concept was explained at the three of the larger companies visited: OMRON, Fanuc and IBM. The way to achieve global production is by using data to first ensure quality is constant across a company's operations. However, there is a difference in how the data for this is stored. One way of doing this is storing data in the Cloud. This means that the data is stored on a central server. This requires significant computing power but this can be spread across different physical locations, this means the utilisation of computing power can be optimised. This technique is used by OMRON. However, several problems have been identified:

- The network becomes costly to maintain and operate.
- There is a real time latency between the data being collected and any response occurring. In some applications this is unacceptable.
- There are many concerns about the privacy of the data and cyber security in Cloud-based computing. There have been notable instances of data stored in a cloud environment being leaked and servers being hacked[31].

In response, a common alternative solution is Edge Heavy Computing.[32] This refers to systems which analyse data nearer its source, so less data transfer is required, and resilience is further improved. This means that data can be kept in a network core inside the company's firewall improving cyber security and privacy. Edge based computing is used by Fanuc and Preferred Networks.

Some of the companies visited had on-going development in a series of tools and applications designed to analyse data collected. However, this was something METI found companies knew they least about, as organisations were collecting more data but not necessarily knowing what to do with it. The scale and scope of all the applications are moving from pure data analysis towards AI based on machine learning. The main examples seen were; the Sysmac system operated by

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[27] IBM Is Blowing Up Its Annual Performance Review, Claire Zillman, Feb 2016, http://fortune.com/2016/02/01/ibm-employee-performance-reviews/ , accessed 14th July 2017
[28] *introduction to FANUC*, FANUC, 2016-II
[29] What is Global Production, IGI Global, https://www.igi-global.com/dictionary/global-production/12257/ , accessed 14th July 2017
[31] Dropbox Hack Cloud Storage, Andrew Griffin, 2016, http://www.independent.co.uk/life-style/gadgets-and-tech/news/dropbox-hack-cloud-storage-company-hacked-potentially-revealing-over-60-million-passwords-a7218521.html , accessed 14th July 2017
[32] Edge Heavy Computing, Preferred Networks, 2017, https://www.preferred-networks.jp/en/news/pr20170315en , accessed 14th July 2017

OMRON[33], the Lumada system created by Hitachi[34], and Watson, which is a tool developed by IBM[35]. At present, the Sysmac range of machine controllers can create, integrate and perform actions on information at high speed. This is because the Sysmac controllers can conduct the analysis, rather than, as is traditional, by a secondary computer mining data coming from a controller. This 2-stage method is traditional due to the fact that controllers must be highly reliable and building capacity for them to analyse data increases their risk of failure. It is thus a large step forward that OMRON has developed a reliable controller with this capability. Many systems require human decision making, but Omron aims to adapt this tool to be cognitive and capable of making intelligent decisions by learning from human decisions made in the past.

At the other end of the scale, the tool developed by IBM is globally ground-breaking in moving towards AI. Watson is essentially an incredibly smart database, and the most successful attempt seen at a fully cognitive system. This means its entire functionality derives from learning from other things. It is a huge web of interconnected lumps of data that it has collected and uses to optimise whatever task it may be doing. This allows it to make intelligent decisions based on many different sources of information. When others use Watson, IBM ensures that all data that it deals with is private, but that Watson can use the experience itself to learn and develop. This means it continues to be the dominant force in cognitive computing. Companies visited which could manage and visualise manufacturing data effectively already were aiming to implement a cognitive technology in their organisation. However, many were unsure if they should outsource this analysis or develop it in-house. The importance of such tools found across the visits supports both British[36] and Japanese[37] governmental papers which outline AI as a key emerging technology.

Many of the Japanese factories visited felt as though they were behind the rest of the world with regard to data collection and analysis. One reason for this was highlighted at DAIKIN, explaining that issues stem from the fact that their focus in the past has been towards traditional lean Japanese methods of production. Unlike other companies whose processes for data collection have arisen naturally from the implementation of automation, DAIKIN has placed an emphasis on low cost, highly efficient solutions. These solutions are suggested by employees as 'quick fixes' which often make no use of industrial automation in the traditional sense. Instead, gravity is exploited

[33] Sysmac platform, Omron, https://industrial.omron.co.uk/en/products/sysmac-platform , accessed 14th July 2017
[34] Lumada, Hitachi Insight Group, https://www.hitachiinsightgroup.com/en-us/lumada.html , accessed 14th July 2017
[35] Watson, IBM, https://www.ibm.com/watson/ , accessed 14th July 2017
[36] Future of Manufacturing, Government Office for Business, Innovation and Skills, 2013, https://www.gov.uk/government/collections/future-of-manufacturing , accessed 14th July 2017
[37] New Robot Strategy, METI, 2015, http://www.meti.go.jp/english/press/2015/pdf/0123_01b.pdf , accessed 14th July 2017

through counterweights that provide effective low-cost solutions to problems. While this kaizen method provides both employee engagement and very inexpensive solutions[38], it means that next to no sensors exist and little data is collected. Perhaps this is partly because the employees are trusted to fix problems autonomously or at least monitor the line proficiently. The only area in which more extensive data collection does happen is to monitor the positions and status of AGVs around the factory. Therefore, while the firm considers cyber-physical systems a priority and makes great use of them in its factory, it shows that traditional Japanese manufacturing techniques such as poke-yoke may be a hindrance to the advance of data driven digitalisation. Now DAIKIN are investing heavily in the introduction of a data collection and visualisation to catch up to global trends of data usage. However, first DAIKIN must standardise their plants. This requires a large investment as their sites are all custom designed and edited by the workforce in each location. This represents a large barrier to them being able to use 'big data' effectively as they can't as yet compare production across sites.

4.3 Cyber Physical Systems

In the following section, the use of Cyber Physical Systems (CPS) in the factories visited is explored. Further analysis is focused in three key areas: (i) the physical difference between the Systems employed; (ii) the differing proportion of the company operations which utilise Cyber Physical Systems; and (iii) the different applications of Cyber Physical Systems.

The visits highlighted two distinct ways in which Industry 4.0 and the Robot Revolution were physically employed in the factories. The best examples to illustrate this distinction are the directly contrasting methods of IBM and Fanuc. IBM does not manufacture goods, instead offering software services to customers. However, it still uses Cyber Physical Systems (CPS) in the form of Watson[40], Watson is IBM's cognitive computing offering and is able to conduct advanced financial analytics, supply chain analysis, support human decision making and even create ingredient combinations for chefs. It is a key tool in improving the resilience of companies through analysis of external data, in particular in improving supply chain resilience. In contrast, Fanuc primarily manufactures products, using fully automated lines to build physical products. Therefore, their implementation of Cyber Physical Systems is very different to IBM.

Fanuc connect the robots to a Factory Talk View SE system[41] allowing operators to monitor the status of all the robots in the factory from a

CASE STUDY

DAIKIN

DAIKIN are one of the world's leading manufacturers of air conditioning units. The factory visited is located in the Kusatsu-Shi area in Shiga prefecture and designs and manufactures room air conditioners; air purifiers; water heaters; and underfloor heating systems. In 2011 they were certified as a Super Green Heart Factory, reflecting their efficient and environmental approach to their manufacturing operations. Their lead time was cut from 63h to just 4h purely based off of employee suggestions. The operations use a mix of manual and automated processes, with manual labour being used for the more dexterous and precise tasks, such as the insertion of copper coils. The air conditioning factory was visited where production involved pressing and bending sheet metal and assembly of the electronics and final products. There is limited data being shown throughout the factory, with the workers scanning a physical barcode on the product to find the required materials and processes. The factory shows extensive use of Kaizen throughout, with employees creating simple DIY solutions to issues, such as custom AGVs for automated movement of materials, and counterweight pulley systems to lifts pallets. Every production machine they had was designed by employees and not separate engineers, showing off the power of the continuous improvement culture they had created.

[38] Imai, Masaaki (1986). Kaizen: The Key to Japan's Competitive Success. New York: Random House

[40] Watson, IBM, https://www.ibm.com/watson/, Accessed 14th July 2017

[41] Factorytalk view SE, Rockwell Software, http://www.rockwellautomation.com/rockwellsoftware/products/factorytalk-view-se.page, Accessed 14th July 2017

single screen. This shows whether the robot or machine is in an alarm or stop status, and robots can be selected to bring up the human machine interface (HMI) for the selected robot, and an additional camera view to show the live position of the robot. From March 2018, Fanuc also intend to begin the Edge Heavy project; robots will be connected to a network, with the data being backed up on an external server for increased safety and analysis options to improve resilience to unexpected events and cyber-attacks. To summarise, while Fanuc uses CPS as a method for better control and monitoring of production machinery, meaning that the physical condition of the production machine has more importance, Watson is designed as the final product or service to be offered to customers, and relies on advanced software design rather than a physical interface. This is a clear distinction between the wide range of CPS solutions available.

In addition, there are differences in the proportion of the manufacturing operations that utilise Cyber Physical Systems. Two examples representative of the different approaches are Omron and Fanuc. The Fanuc factory is close to being 100% automated, only using a human workforce to monitor and maintain the automation. On the other hand, Omron is aiming for 50% automated and 50% manual labour, with the automation only being used where it is more efficient than the manual labour, for example in loading the SMT machines or in cleaning the PCB boards.

These differences are due to both the company products and key selling points. Fanuc sell manufacturing machines including CNC machines, 6-axis robots and Delta pick and place machines. By carrying out manufacture using a fully automated line of their own products, it shows customers that Fanuc have confidence in their own abilities, showcases the range and capabilities of the machines, and helps to show that they are market leaders, in addition to ensuring they have a high productivity rate. If Fanuc instead used a partially manual workforce it would suggest to customers that their products are not fully capable and were also unable to fulfil every process needed. Omron, on the other hand, manufacture a wider variety of products, and the particular factory visited as part of the research trip built PCBs, which were not manufactured in the Fanuc factory visited. Therefore, they require very different processes, such as the assembly of small components, where the precision and flexibility of a human worker can offer a more efficient solution. This explains in part the higher proportion of manual labour. The other reason is the culture at Omron and their approach to human resource management. Omron desire to maintain their workforce and not 'lay off' personnel due to increased automation (see more on this theme in section 6.3.). Therefore, in order to fit with their company culture, they retain a mixed operation comprising both automation and manual labour, despite manufacturing some products similar to Fanuc.

It is important to consider how the different mixes of Cyber Physical Systems will affect the future development of the two companies. It is arguable that Omron's desire to maintain their manual workforce will limit their ability to develop as machines become more advanced and more efficient than the human equivalent. This could allow competing companies to become more efficient and cost-effective while their own productivity is restricted. However, FANUC are at risk of having a lot of hard automation in place and thus not being about to be flexible in the future where, as many world events of 2017 alone have demonstrated, anything can happen.

Hilltop use Cyber Physical Systems effectively having data move from the programmers to the CNC machines which can be anywhere in the world, most effectively by sending code to the US so machines can work on it over their night cutting the lead time in the US. Even so they still have many options for future development as they are active in considering how the market and technology is changing and how they will respond. For example, they are developing robots, as well as original manufacturing products and machines, which gives them a variety of options in the future and increase their resilience to changes in the market. This is possible as they are flexible in not only their product range but also their business model. In contrast, Omron's product range is very established, and they are less likely to break into new markets with reduced competition. Hence they have to compete on the cost and quality of their products, which can be enabled with greater use of Cyber Physical Systems.

A third difference between the companies' approaches to Cyber Physical Systems is the System's capability. This varies between each company according to their individual needs. For example, in Fanuc, the systems are used for visibility, allowing the operators to see the status of the systems and be alerted to any errors. However, they are much more advanced in the art of interconnectivity. Robots and machining centres communicate with AGVs and automated warehouses to keep a flow to production even when it is fully automated and carried out in machining cells. Similarly, DAIKIN uses Cyber Physical Systems for visibility, but to a lesser extent. Their systems are generally small and developed in-house by employees trying to quickly solve issues and improve the efficiency and productivity of the process. They have some network capability, with monitors being used at workstations to inform the worker of the current part, or to indicate which material is required, but they are not used for automated control of the factory, and also do not collect and store a vast amount of data for analysis. Omron use their systems to interact with the line in addition to improving visibility. Their system alerts the floor manager if there is an error, and allows them to then interact with the station to find the problem and to solve the issue via the Cyber Physical System. IBM, in complete contrast, uses the Cyber Physical System not by interacting directly with a manufacturing line, but rather by analysing data sources and providing recommendations to the floor manager or user.

The reasons for these are as follows. The first is concerned with the level of maturity each company has with respect to Industry 4.0 and the Robot Revolution Initiative. For example, FANUC are heavily involved whereas DAIKIN concentrate more on efficiency and productivity. The second is due to the nature of the operations taking place. For example, Fanuc is fully automated and so needs more capability from its CPS than DAIKIN. Finally, there are other influences that affect their choice of CPS capability. For example, in IBM the CPS is the final product, and so it has to be as capable as possible. OMRON also aim to use their factory partially to inspire and lead other OMRON factories in the pursuit of Industry 4.0, and so they need to have a highly capable CPS system.

4.4 Digitalisation of operations – company strategy

All of the operations heavy companies visited had some form of a strategy to implement digitalisation in their company's operations. Some were more progressed than others, but some distinct similarities were found across all the strategy's being carried out or presented to us. Thus, the general strategy to implement Industry 4.0 can be split into three distinct parts:

- **Standardise** operational practises across plants.
- **Visualise** operations across plants by collecting relevant data.
- **Optimise** operations by an appropriate or relevant technique, leveraging the data collected from step two or otherwise.

Standardisation is seen as key to Japanese firms implementing Industry 4.0. As discussed in section 4.2, if they have utilised Kaizen successfully across their plants there are inherently significant differences across them, as different suggestions from employees have been put in place. This makes standardisation key to be able to offer the same digitalisation solution to all plants, or even compare data between plants. This was identified by all the factories visited. DAIKIN was in the process of standardisation across the globe, whereas OMRON had standardised lines for specific products across its Japanese sites making the same controllers. This was where many Japanese factory's felt they were behind the west, specifically the US who are known for their standard procedures developed due to their high turnover rates.

Visualisation was very much seen by the manufacturers visited as the next step to digitalising operations. This came as quite a surprise as there was much more of an emphasis on it than previously observed in the UK, for example. Visualisation involves collecting data at key points in a plant to be able to track its progress as well as identify problems live. A key point from this is that different plants need to be compared 'like for like' based on this data, showing the need for standardisation. All of the operations heavy plants visited gave the group a vision of a control room where all lines can be monitored and even controlled. For FANUC, their "vision" was more of a reality, whereas other companies, such as OMRON, talked about it being years away.

Once a plant could be "visualised" the optimisation of operations was talked about. Different companies prioritised different things as the best Industry 4.0 techniques to utilise are more specific to a plant's nature or problems. DAIKIN for example wanted to first use big data and machine learning to create a "non-stop factory". The idea being that they would use data to ensure nothing broke down and everything could run smoothly. Their second priority was to introduce collaborative robotics to save on labour costs. Other plants had different priorities such as OMRON who had already implemented the visualisation part of their strategy and are moving towards using data to predict the breakdown of their machines.

The main worry firms had about standardisation, especially observed by middle management, was that it may prevent continuous improvement as higher management are resistant to changing processes as it will affect how they are visualised and make different sites incomparable. This being said, if done successfully it could be a way to get small improvements made at one site to be transferred to the others, giving employee suggestions cross plant power. It could also be a way to help incrementally implement digitalisation into mechanical solutions.

4.5 Conclusions

The following section describes the three most important findings of the research project in terms of the transformation of manufacturing operations due to digitalisation.

Firstly, it is clear that while many large corporations and technology heavy industries are in the process of implementing a digitalisation project, there are many cases in which such a move would be detrimental to the operations of the firm and this should not be pursued. For example, in traditional or highly skilled industries, such as sake brewing, the hand craftsmanship is more highly valued and delivers higher quality produce.

Secondly, traditional Japanese manufacturing techniques such as Kaizen and Poka Yoke may actually be forming a barrier to the advancement of the Internet of Things and data collection. This is because handmade, low cost solutions are unlikely to be digitalised with sensors and electronic equipment. While other parts of the factory will be able to be connected to an IoT network, these areas may be excluded from the system, forming a gap in the visualisation of the factory.

Furthermore, the choice of Cyber Physical Systems may affect a company's ability to grow in the future. For example, 100% of Fanuc's operations use Cyber Physical Systems, and so as their production machines improve they will stay at the head of the market. Omron, on the other hand, are limited by their desire to maintain a manual labour force which will put a cap on their potential efficiency, limiting their growth.

Finally, there is a clear route via which Japanese companies are trying to digitalise their operations. A clear pattern in strategy across firms showed what was seen as the most highly valued: the visualisation of factories. This is perhaps because there are many highly skilled operations engineers in Japan, and this will enable them to progress operational improvements quickly. In contrast, by increasing standardisation, it could be to try and stop small operational improvements, which are stereotypically Japanese, and which may prevent Japanese firms from fully embracing Industry 4.0, thus risking falling behind other countries manufacturing practises.

5 Supply Chains

5.1 Introduction

For a number of years, the structure and dynamics of manufacturing firms' supply chains have acted as a critical means through which they can influence their competitive position. Operationally, the careful management of supply chains has remained crucial to avoiding difficulties such as the Bullwhip effect[42] and ultimately preventing the costs associated with excessive inventory or a lack of stock. The methods used by firms to generate operational improvements in their supply chains have evolved and developed. Following the industrial revolution, firms were faced with the "Make or Buy" decision about which processes to pursue and which to outsource, following such decisions, manufacturing firms established relationships which consisted of material exchange. Moving through the 1960s, Japan led the way in improving the operational efficiency of a company's supply chain. Extensive research was done to help generate an understanding of how information exchange can help to further streamline the material exchanges between firms and to ultimately improve efficiency and effectiveness of these material relationships. At that time, it was fashionable for firms to increase the information sharing with firms which were vertically proximal in their supply chains. Such projects negated the effects of the Bullwhip effect through better anticipation of supply and demand fluctuations. A range of systems and strategies have helped to improve the supply chains of firms and nowadays are near ubiquitous. Throughout the project, these traditional vertical material and information flows were widely observed, for example, ERP systems (e.g. SAP, as seen at Kyocera) and knowledge sharing (e.g. Daikin).

The following analysis begins by generating an understanding of how in the age of digitalisation, new technologies and their tools are helping to further condition these vertical supply chain relationships. However, additionally, in the resource based view of the firm, supply chains can act as a mechanism through which firms can obtain a scarce resource and ultimately leverage it to generate a competitive advantage. Indeed, firms are looking to expand their traditional vertical relationships. Firms are also looking to augment their individual capabilities beyond their traditional core competencies, through the exploitation of digitalisation to form new horizontal relationships. The following analysis helps to understand how and why these new horizontal relationships are being initiated, specifically as viewed through the digitalisation of manufacturing lens. For each theme, case studies are used to demonstrate how the vertical supply chain has developed to a hygienic level, at which point it stops being a managerial priority. Subsequently,

[42] Forrester, Jay Wright (1961). *Industrial Dynamics. MIT Press*.

each case study investigates the type of horizontal collaborative relationships being formed.

5.2 Internet of Things

IoT products are already being discussed in the biggest technology firms due to their potential to impact on company supply chains. IBM are looking at developing smart cities in the future that will use IoT products to allow the various facets of a functioning city to be interconnected and communicate with each other. The potential impacts of these developments are profound and range from vastly increased functionality (efficiency, capability, visibility) to reduced human operator input. In a smart city all constituent elements could be managed from a central hub due to the interconnected nature of the elements leading to more effective supply chain management; the increased knowledge will be available faster and more readily manageable. This will inevitably facilitate collaboration between the actors in a supply chain. Indeed the genesis of the concept of interconnectedness between city wide infrastructure functions has already occurred; in London consolidation centres exist where transhipment activities already occur. For example, 25 different lorries may transport stock to a distribution hub in the outskirts of the city where the stock to be transported to congested areas in the central areas of the city is loaded onto one lorry meaning reduced traffic. It is an operation that would undoubtedly be facilitated or enhanced by IoT products. The challenges are significant however. The biggest concerns for IoT products revolve around security of the data being collected and transmitted, e.g. if city wide infrastructure such as utilities were to be compromised the ramifications would be severe and far further reaching than they would be without the interconnectedness. Furthermore, smart cities are national assets that will therefore require national standards to be defined for effective functioning. It is imperative that the government is involved in setting the standards in conjunction with firms that have the greatest expertise in the area. This movement by IBM and other companies has strong undertones of Japan's METI's 'Society 5.0' movement, which is discussed further in section 8.4.

The potential impacts of IoT products are not limited to smart cities that are visions of the distant future. Indeed, Fanuc have developed their FIELD system that, amongst other things, enables zero down time via IoT products. Machines are able to monitor the effectiveness and quality of their own operation and transmit the data to a central hub that can then accurately predict when a machine will go down. This is only possible due to the interconnected nature of the machines. This can be extended to give end to end visibility for efficacy of machine operations for all tiers of the supply chain, thereby greatly increasing supply chain efficiency. However, there are many challenges in encouraging firms to engage with and adopt IoT products. The concern about data security is a very powerful barrier to entry for these products, indeed if sensitive data for a large global firm such as Fanuc were to be compromised then the financial, social and environmental impacts would be severe. This would only increase in severity if an entire supply chain, made up of multiple firms, were to be compromised.

There is also resistance to the adoption of IoT products by various actors in the supply chain as firms do not feel it is required for them to compete. It is a complex undertaking to enable firms in this respect (to transition them to incorporating IoT products) and firms do not feel as the financial benefits are worth the capital input at this stage. Indeed an executive at Omron stated that they have developed 'IoT products that are ready to be deployed, however they have not deployed them in practice because their customers do not engage in processes that require IoT products'.

All of the above relates to how firms can utilise IoT products to improve their operational supply chain via sharing of information and improvement in material flow efficiency. Perhaps the greater goal is the creation of a strategic supply chain in the form of a transition from linear supply chains to business ecosystems. Indeed, it can be argued that many firms such as Kyocera and Murata's operational supply chains are at a hygienic level, where the propensity for marginal increase in value for a given level of input resource is outweighed by the propensity for the marginal increase in value at a strategic level should the same quantity of resource be dedicated to facilitating collaboration in the business eco system.

If Japanese firms are all going to transition to a business ecosystem then there needs to be the creation of a common multi party value delivery platform, such as IBM's Watson platform. METI need to work with a consortium of global private sector firms to jointly define this platform; this would mean that not only is the platform more likely to be suitable for industry adoption but also that is more likely to be adopted by the aforementioned firms due to their input in the design process. This is something that is not only not currently happening, but also something that will require a fundamental shift in the business culture of Japan, so that firms are willing to take advice from government institutions such as METI (more on this is discussed in section 8).

5.3 Big Data

Continual advancements in technology at all levels of the manufacturing supply chain has enabled an increase in the ability to store and collect data from a wide range of inputs. Japanese companies such as Preferred Networks are at the forefront of developing machine learning algorithms to process vast quantities of raw data and provide meaningful insights to reap the benefits of informed decision making. This section will describe how big data is being used in Japan to improve the flow of material and information vertically in the supply chain, and the role big data will play in furthering the development of collaborative business eco-systems.

Upstream flow of information such as demand forecasting and market trends from the end user is essential for strategic planning. This data must be aggregated from a variety of complex, interrelated external sources. Here big data offers the foundation for increasingly sophisticated analysis. Preferred Networks has begun to see benefits from this with their work in the healthcare sector. Personalised medical data can be compared to a vast history of prior cases, resulting in earlier diagnosis and improved information regarding future patient needs. Pharmaceutical companies use this information to adapt their operational strategy, saving costs and resulting in superior patient experience. Upstream flow of operational information between suppliers has previously been responsible for a reduction of the Bullwhip effect, and application of big data has markedly improved the sophistication of such operational insights. By sharing locally generated conclusions from raw factory data, the requirement of compatible raw data formats across the supply chain is relaxed, and data traffic is lowered as the bulk of data does not need to be shared.

Alongside strategic benefits, improved information from big data in individual organisations is causing operational benefits from increasingly sophisticated stock level management and production scheduling. Fanuc offers further operational benefits across the supply chain by using big data to more accurately predict machine downtime and required maintenance scheduling. The changes to any single parameter prior to failure are subtle, making it difficult to attribute significance to results. By analysing the sensor output history prior to failure for many robots, machine learning algorithms are now able to forecast failures up to three weeks in advance. This brings Fanuc robots closer to the ultimate goal of zero downtime, increasing predictability and trust between suppliers and customers. Another strategic benefit of improved information, and information sharing, was found at Daikin. Their seasonal demand variation is vast, with 3 times more demand existing in the summer months. Daikin intend to equip every supplier with a digital system to improve information flow and help ease this variation. They believe that in this way it is important to treat their suppliers like they are part of Daikin. Similarly, Omron use an online system to communicate with their suppliers, and explain that they want to "build trust" with their suppliers to take the lead in these such successful relationships necessary in the future of digital manufacturing.

Big data offers the potential for compression of supply chains through improvement in understanding of process parameters. Historically many processes in manufacturing have been optimised in isolation as dependencies between processes are complex. Sequential processes are therefore commonly executed by separate specialist firms. With sufficient data availability, traceability and processing, the relationships between processes are becoming increasingly understood to the point that process parameters can be adjusted for individual parts to correct for imperfections. The supply chain may then become compressed as a single firm performs multiple processes, producing parts of a higher quality and benefiting from shorter lead-times and lower costs. Hilltop has brought surface treatment capabilities in house to increase responsiveness to customer needs and to gain the capability of correcting variance in hole diameter in their prototype part offerings by adjusting later process times.

5.4 Cyber Physical Systems

A supply chain consists of both physical flows (e.g. raw materials and finished goods) and information flows (e.g. procurement and sales data). In Japan, the Industrial Value Chain Initiative (IVI) encourages the use of Cyber Physical Systems (CPS) throughout supply chains. CPS integrate, coordinate, synchronise and transform these flows to create efficient, intelligent supply chains that are flexible and resilient to internally and externally generated disturbances.

Logistics systems include the components of the supply chain responsible for planning, implementing and controlling the forward and reverse flow of goods, services and related information. Davenport[43] highlights the use of RFID (Radio Frequency Identification) tags for monitoring the movements and location of products. Many cases were reported of successful use of RFID tags in supply chains in Japan; uptake has increased in recent years as the technology has become more and more affordable. For example, OMRON used RFID tags to track parts though their factory where the tags were put on by their supplier so parts could be tracked from the moment a delivery was met. Applications of RFID tags include inventory management and lot tracking. They are also increasingly used to pass information that is linked to physical flows between supply chain nodes. This reduces the need for direct communication channels between each supplier – production information can be read from and written to an RFID tag which moves with material and products – creating supply chains that are both more flexible and more resilient.

Improvements in work planning and scheduling are driving efficiency improvements in logistics systems in Japan. Traditionally these tasks have been carried out by skilled workers. Hitachi Digital Solutions have employed machine learning to enable a CPS to understand and optimise processes for receiving orders, procuring material and directing production. Coupled with business analytics tools and IoT technologies the CPS can take account of uncertainty and dynamically

[43] Davenport (2009), accessed at http://www.rfidjournal.com/articles/view?7166 on 26th November 2017.

respond to events to ensure that customer orders are delivered on time. This system has been implemented in a number of firms, across a range of industries. When visited, they gave the case study of a Japanese steel mill who have seen significant improvements in the operational efficiency of their supply chain. This frees up time for workers to focus on developing strategic relationships throughout the value chain. Similarly to Hitachi's offering, IBM's Watson can be used to optimise supply chains and networks for efficiency and resilience, and has had great success in doing so. More on these offerings is discussed in section 7.

Autonomous Guided Vehicles (AGVs) can be used across the supply chain to maximise productivity - 24/7 operation is possible - and improve safety, reducing manual handling and the risk of human error. Daiken use AGVs, which have been developed in-house, widely across their own internal supply chains and are working with their suppliers to share best practice. Whilst many Japanese firms are aware of the potential benefits of these CPS, few have implemented them as successfully as Daikin. Increased investment is required to develop off the shelf solutions which should increase uptake of AGVs.

Firms often struggle to match skills and resources with demand in increasingly volatile, increasingly global, industries. Hilltop Corporation is using CPS to enable distributed design, development and manufacturing. Hilltop's sites in Japan and USA share skills and resources; information is exchanged through a CPS, with programming done in Japan but some CNC machining completed in the USA. This reduces the financial and environmental costs of moving material. A key driver of the rapid prototyping industry is fast lead times; comparatively 'local' manufacturing gives Hilltop and its partners significant advantage in an extremely competitive market. Further expansion of this global network is in the pipeline, increasing potential locality. By working collaboratively with global partners Hilltop can leverage its design and rapid prototyping capabilities to meet local needs and create mutual competitive advantage.

5.5 Conclusions

As can be seen from the above analysis, the age of the traditional, linear supply chain is over and a new company relationship structure has dawned. This paradigm has been facilitated by the development and dissemination of digitalisation. With respect to the operational importance of supply chains, firms are finding reduced administrative costs and, consequently, are obtaining improved efficiency. As described above, firms are able to track products more accurately through IoT initiatives whilst Big Data and cyber-physical systems enable streamlining of processes and institutions. Through these digital concepts, firms have been able to steadily improve the performance of their supply chains. The gradual development of these systems has meant that most companies are satisfied with their existing RFID or barcode systems, those they had in place, and were hesitant to innovation. As supply chain management has been made easier, its proportional cost, relative to other operating costs, has fallen to a sufficiently low level: many of the firms being visited no longer deemed their supply chain to be of particular concern, and expressed the view that they did not need to work with their suppliers to deliver any further gains. Primary decision-making agents had reduced emphasis on managing their supply chains. When looking to create and manage relationships with other firms, firms are no longer focused on the operational benefits they might achieve. Instead, Japanese firms have experienced a new type of horizontal relationship which they deem to be present far greater potential in transforming their market and their product-service systems.

The combination of these vertical and horizontal relationships might be considered as a unit piece of a business ecosystem, whereby firms identify value creation opportunities to exist not solely down their traditional supply chain, but importantly through horizontal relationships. These horizontal relationships, which are primarily collaborative have facilitated the exchange of knowledge, rather than the exchange of tangible products. Through the exchange of such knowledge, firms have increased their capabilities beyond their traditional core competencies, and view this as critical to their ongoing sustainability as a firm. The above examples show how indeed this digitalisation theme have either motivated or facilitated these horizontal relationships. As a wider trend, these horizontal relationships represent a move towards open innovation. A failure to participate in such initiatives is deemed to spell failure of the innovative capacity of the firm and ultimately the firm itself. A key learning from this research was the feeling that: Only through the successful exploitation of Business Ecosystems can firms create the sort of paradigm-shifting product-service systems which make up the consumer demand of the future.

Despite the successful emergence of some of these network structures, there remain several barriers to continued development. Many companies identified that a failure to generate standards, for example in data format, was slowing more widespread collaboration. Furthermore, firms were occasionally concerned about data security when performing data exchange along the supply chain. As described above, the government believes it has a critical role to play in the further facilitation of these horizontal relationships. A range of initiatives have been formed as a means of creating commonality and consensus between parties. However, as described above, such work has been met with mixed reactions- often negative. In reality, firms tend to form their relationships in three ways:

1. Organic relationship initiation - Preferred networks and Hitachi.
2. Establishment of consortiums – ASTEM.

3. Mutual support of research institutes – ATR.

It is envisaged that going forwards the companies which can embrace, initiate and manage their business ecosystems most successfully will be those companies which can achieve persistent competitive advantage.

6 Human Resources

Human resources are of huge significance in the facilitation of digitalisation. Despite this fact, it is the most difficult are to specify criteria which qualify a company, or industry, as 'digitalised'. Highlighting its importance, developing human resources was found to be the most important focus for the government, according to discussions with METI. Looking at the synergies achieved, levels of resistance, and systems and criteria surrounding talent management, among other things, can give an indication of the current and potential state of companies. Those that have recognised what will be required from them, and how their human resource strategies need to change, in this sense are likely to excel in digitalisation, whereas those that have not may find themselves falling behind. For example, Omron is among the companies that recognise the strategic importance and, as such, have a dedicated "human resource strategy division".

The key areas found to fall within the effects of digitalisation on human resources, and in some cases vice versa, were found to be collaboration, talent management, impacts upon the workforce, and the digitising of human resources. These are discussed further, in relation to the companies visits and discussions held, in the following sections.

6.1 Collaboration

Within the digitalisation of industry, collaboration becomes vital. This takes many forms, for example: between different locations of a global company, within an industry, across different industries, with universities and consortiums or with government. As such, managing collaboration becomes a key area on which human resource management must focus.

An example of collaboration between companies was found between IBM and BMW, where the former provides a digitalised solution and the latter provides the interface or application. They are working together to produce cars that are connected to IBM's product, Watson.[44] As with all collaborations, this will add complexity to the role of management. When discussing collaboration between industry and universities, it was often stated by companies that there is significant collaboration, however, upon visiting Waseda University in Tokyo and the Kyoto Institute of Technology, a question was raised as to the extent of this collaboration in actuality. It appeared to be the case that both of these universities were developing technologies in line with the theme of digitalisation but had not yet thought about the application of the research they were carrying out so much as the value of the research in

CASE STUDY

MURATA

Murata was traditionally regarded as a very closed company, tightly holding information regarding its confidential production processes. However, following current trends they are beginning to embrace open innovation by establishing an open innovation department to collaborate with universities and industrial partners. One tool being used to achieve this is 'Ideathons' to bring firms and universities together to tackle issues such as the aging demographic. However, members of the open innovation department have faced some resistance from within the firm, as more traditionally minded employees are cautious of the concept of open innovation.

[44] Guerrini, F. BMW Partners With IBM To Add Watson's Cognitive Computing Capabilities To Its Cars, Forbes.com, 15 December 2016, accessed 14th July 2017 https://www.forbes.com/sites/federicoguerrini/2016/12/15/bmw-partners-with-ibm-to-add-watsons-cognitive-computing-capabilities-to-its-cars/#6df9ef371a90

its pure form despite the evident significance their research could have. Thus, there was perceived to be a lack of commercialisation of technology; this is something which the UK struggles heavily with. Closer management of collaboration between industry and the universities would enable greater value to be obtained and may increase the rate of adoption of digitalisation.

Global integration of companies has been made possible through digitalisation, with its positive effect on connectivity via IoT technologies. For example, Hilltop has equivalent factories in Japan and the USA; they use an online connection with large screens in the style of a continuous conference call to reduce the barrier between the different locations. This permits them to communicate directly, where the time difference allows. Hilltop's factory in the USA actually lacks the programming section of the workforce found in the Japan headquarters, and thus the detailed programming of the parts produced in the USA is designed remotely in Kyoto. One advantage of this is that it enables programmers in Japan to programme overnight, ready for the USA factory's use the following day. It also provides a leaner organisational structure, without the duplication of a whole team of people.

As is common within digitalised industry, a number of the companies visited have adopted a strategy of open innovation. This includes Preferred Networks and Fanuc, who have also been collaborating with each other, Kyocera, who have recently established an open innovation department, and, more notably, Murata, who until recently had a closed development strategy. In the case of Preferred Networks, the use of an open innovation strategy is helpful in publicising the company and increasing awareness for recruitment purposes. This is discussed further in section 6.2.

6.2 Talent management

Talent management is another key area within human resource management that is impacted by digitalisation. With the advent of a new digitalised era, skill requirements are changing. This is placing pressure on the recruitment of sufficiently skilled people.

Preferred Networks are a relatively small company with a high growth rate and thus are aiming to recruit as aggressively as possible. Due to the skill requirements, much of their recruitment is achieved through recruiting heavily from competitors. As mentioned in section 6.1, increased publicity gained through open innovation aids this process, since this is seen as an attractive part of working at Preferred Networks, as well as being effective publicity in itself. Additionally, they are now having to rely on poaching activities less, as company recognition is increased through competitions like the Amazon Picking Challenge (2016). Murata is in a similar position, recruiting only 1 or 2 sufficiently skilled employees each year for their innovation centre. As with

Preferred Networks, it is probable that their open innovation strategy aids this process. It was noted that they have no clear repeatable route for recruitment.

Both Preferred Networks and Hilltop aim to recruit from a variety of backgrounds, areas and countries. Preferred Networks believe this is what gives them an advantage in collating a number of viewpoints and offers a view of overarching areas to be tackled globally. For example, employing an architect has provided them with the insight needed to attempt to revolutionise the way buildings are designed. Hilltop, on the other hand, recruit from a variety of backgrounds with the view that the necessary skills can be taught on the job, instead focusing upon personality and fit. This is potentially of particular significance given that they are turning away from traditional Japanese views, and focussing on aspects such as increased opportunities and responsibilities for female employees. 60% of all recruits at Hilltop come from unrelated backgrounds, with all recruits paid the same, regardless of their company role. This is likely due to their strategy of moving employees around the company to achieve a more holistic understanding of company operations. Pay is related to the length of time spent at the company rather than the job role. This is in line with Japanese traditions, despite their more forward thinking activities in other areas. Instead, differing work responsibilities and performance is recognised through bonuses. However, upon discussion with employees, there was doubt as to whether management have sufficient knowledge of individual performance to be able to do so. Thus, it is thought that bonuses are commonly given as a set proportion of the wage, thus the effectiveness of this scheme is questioned.

As mentioned above, Preferred Networks recruit a variety of nationalities, with 10% of employees currently from overseas. They have set a target to increase this to 40%. Similarly, 44% of ATR employees are international. Both of these companies have not felt the skills shortage that is seen within the industry to the full extent; Preferred Networks' issues originating from the aim for trans-industry recruitment and lack of recognition that follows instead. Given this correlation, it is hypothesised that companies employing internationally are less impacted by the skills shortage as they recruit from a wider pool. Within Hilltop, it was noted that European migrant employees were perhaps not subjected to the same cultural norms of staying later than necessary, to ensure that one leaves after their superiors, or not taking their allocated holiday leave. This could be a reason as to why international workforces are not adopted more widely, as they may be seen as less fitting with the culture of traditional Japanese industry. It is worth noting that residency for migrant workers in Japan is granted based on a scoring system, which favours younger workers. This could be a contributing factor for the comparatively

CASE STUDY

HILLTOP

Hilltop is unique among other Japanese companies in its forward thinking approach to human resources, particularly in their views on recruitment. The most notable difference is that Hilltop hire entirely based on personality and fit. In fact, over 60% of all their employees do not have a background in engineering and are languages and humanities students. As a result their employees require more training and spend their first two to three years at the company trying all the roles to get a more holistic understanding of Hilltop. They also differed in the fact that they had a much younger workforce and a higher proportion of female employees, allowing women to take on the same roles as men.

younger workforce at Hilltop.[45] On the other hand, the younger workforce could be due to the modern approaches adopted by the company appealing to the younger generation. Recent changes to the entry requirements for immigrants to Japan favour those coming from innovative SME backgrounds; as such an increase in this type of migrant workers is likely to be seen in coming years.[46]

In the UK half of all employees have felt a digital skills gap[47] and this is particularly felt among the younger generation[48]. The ageing demographic present in Japan, alongside the trend of decreasing population is thought to catalyse the skill gap, which would otherwise be similar to that seen in the UK, according to insight gained within a meeting with ASTEM. It is estimated that, by 2060, 40% of the population will be over age 65, which, alongside the decreasing population, will result in Japan becoming a "Super-aged society with no parallel in history."[49] Additionally, this is causing an ageing democracy in which governments are prioritising the older generation. This may be slowing the progress of digitalisation as there is likely to be more resistance to the movement in older generations. Resistance to digitalisation will be discussed in detail in section 6.3. The lower remuneration for young people that remains as a result of ageing democracy prioritising the older generation, even seen in Hilltop, which is the company least constrained by Japanese tradition, may be stifling efforts to encourage young skilled workers to migrate to Japan, where they could earn substantially more in other countries. Many companies, including Omron, whose average age of employees is staggeringly high at 42 years, are worried about this decreasing workforce, to the point that they are planning to expand their recruitment pool to include more women (a positive, but nonetheless forced, movement) and migrant workers, and to alter job roles, through use of collaborative robots and otherwise, such that employees will be able to work for longer and so that disabled people could carry out these tasks. This will be discussed further below and in section 6.3. It is generally thought, by companies such as Hilltop, that the impact of a decreasing workforce could be balanced by increasing automation to reduce the human requirement.

METI believe that the Internet of things is key to solving these social problems, and thus the government is encouraging companies to adopt digitalisation. In this way, automation replacing humans is seen as a

45 Japanese Ministry of Justice http://www.moj.go.jp/nyuukokukanri/kouhou/nyukan_nyukan50.html , accessed 14th July 2017.
46 Immigration Bureau of Japan http://www.immi-moj.go.jp/newimmiact_3/en/evaluate/index.html , accessed 14th July 2017.
47 House of Commons Science and Technology Committee. Digital skills crisis. 7/06/16 https://publications.parliament.uk/pa/cm201617/cmselect/cmsctech/270/270.pdf , accessed 14th July 2017.
48 ACAS. Huge skills gap among UK's young people revealed. 2015 http://www.acas.org.uk/index.aspx?articleid=5369 , accessed 14th July 2017
49 Nippon. Japan at the Forefront of Super-Aging Societies. 15/08/2016 http://www.nippon.com/en/features/c02801/ , accessed 14th July 2017.

solution to their problems, rather than a source of significant resistance, as is the case in many countries around the world. For example, in the UK employees' resistance to automation is seen as one of the largest three barriers to implementing automation. [50] This is largely due to the fear of job loss among employees. On the other hand, METI is worried that jobs will be lost, not so much in the effect it will have on the number of jobs in total, but more that ageing employees may struggle to keep up with the changing skill requirements that follow. Along this theme, the government plan to invest in areas such as data analytics, so people will be skilled in both manufacturing and IT, as is required for the trend towards digitalisation. Companies such as Fanuc are focused purely on designing and building automation and digitalisation technologies, which enable digitalisation of other companies. Thus, their requirements for skills are changing less, as they already require highly skilled operators. However, as Fanuc explained, since they require very skilled people they are 'scared' that these people will want to retire and leave them without an equivalent level replacement. This is due to the fact that their operators are the same people who design their robots; they have an incredibly low number of operators on the shop floor, all with large amounts of technical expertise. This is similar to Daikin, whose operators are so highly skilled that they design much of the robotics themselves. It was felt that, in the future, companies need to move to models such as Fanuc's and Daikin's, and companies and government policy need to aid education and training to allow people to fill more technical roles, as low skill labour becomes increasingly obsolete. Omron, on the other hand, anticipate they will have a similarly dramatic issue in a different sense: they will see a change in the skills required as the digitalisation and automation of their plants increase. They plan to train current employees to combat this.

Although the majority of the skills shortage relating to digitalisation is a result of these changes, in some cases digitalisation is a solution for a skills shortage. This is the case for traditional industries, including Tsukino Katsura and those addressed by projects at the Kyoto Institute of Technology. As is discussed further in section 6.4, in traditional industries skills are generally passed down from master to student, but it is expected there will be a gap in this process with younger generations moving away from traditional industries. In order to ensure these skills are not lost, techniques are being digitised and captured as far as possible.

50 Information age. 2018 will be the year of automation in enterprise. 28/06/17 http://www.information-age.com/2018-will-year-automation-enterprise-123467030/ , accessed 27th July 2017.

CASE STUDY

DAIKIN

There is a strong culture of training within Daikin, showcased by their dedicated training facility, the 'training dojo', where operators are trained in an interactive manner on safety within the factory. Daikin are also looking to design some of their automation systems themselves. Although the skills and knowledge required for this are particularly specialised, they believe they currently have enough sufficiently skilled people, as well as adequate systems for employee suggestions for work design improvements. In the future, however, they anticipate the need for additional recruitment in order to fill this gap. The focus within Daikin's digitalisation is on recruitment of labour rather than the training of the current employees, although the feeling within the company is that this should change and they would like to train their own staff more in the future.

The population in Japan is predicted to shrink by one third by 2065[51]. With the issues discussed above and the declining population, the available workforce is expected to decrease, and thus heighten the skills shortage. Omron, who currently only employ 192 female engineers to their 1594 male engineers, have said they aim to hire more women in order to fill the gap, as well as using automation to adapt job roles such that disabled people could be employed to fill this gap. They are also considering hiring more migrant workers. Omron already have a program specifically designed to target women for recruitment. In addition, they have set a target that women should hold 5% of all positions of responsibility by 2019. However, this goal seems to be treated as more of a CSR activity than one to overcome recruitment challenges, potentially indicating a remaining stigma surrounding women in the work place. Hilltop have a notably lesser stigma against women in technical roles and have already recruited many. Perhaps of significance is the correlation between those that hire from a wider pool of applicants, such as Hilltop recruiting women and internationals, apparently feeling much less of skills shortage. It was noted in discussions at Omron that perhaps there is little absolute skills shortage and that the issue is more in the location of skills; there are thought to be more IT and technically trained people around the Tokyo area than elsewhere in Japan, whilst Omron require these capabilities in Kyoto, as well as other locations. Perhaps they could utilise Hilltop's approach, detailed in section 6.1, to facilitate remote working and thus overcome some of these issues. In fact, the concept of an office in Tokyo was discussed as a possibility, since this is apparently where IoT focussed people generally want to live. It was worth noting that the trip visited both IBM and Hitachi offices in Tokyo to discuss their IoT platforms, supporting this assumption.

In order to combat skills shortage, training is extremely advantageous. Daikin use training as an opportunity for knowledge and skills sharing across their locations, bringing in employees from Thailand to learn skills in their Japanese factory. Omron take this a step further, aiming to help combat the issue of a national skills shortage by offering demonstrations to SMEs whom are finding it harder to keep up with digitalisation developments due to lack of capabilities and resources. Interestingly, KIT explained that they don't struggle to find people as their work is so cutting edge and technical, being a research institute, that they can easily find people to work on their projects; it is the more common place, change management centred digital roles in large manufacturing companies that are harder to fill skills wise.

Beyond the idea of training to enable employees to become sufficiently skilled in order to keep up with digitalisation, digitalisation of industry also has links to training, in the regard that big data and IoT have the

51 Danielle Demetrious. Japan's population to shrink by a third by 2065. 11/04/17 http://www.telegraph.co.uk/news/2017/04/11/japans-population-shrink-third-2065/ , accessed 27th July 2017

potential to help with training and monitoring employees. For example, IBM has been developing the use of personal analytics, which could be applied in this way. This forms one of the types of 'Operator 4.0', seen as a way to implement digitalisation, which is discussed further in section 6.3[52]. Along this thread, Hitachi analyse employees using data. For example, they map employees' interactions and use this information to establish who the most important person is, which helps them identify who may be able to help them make changes.

6.3 Impact on the workforce

The digitalisation of industry has effects on the role of human resources, both on an individual scale and collectively. In the UK and elsewhere there is a notable stigma against excessive automation and artificial intelligence, which may be why IBM avoids using the phrase 'artificial intelligence'. This is likely to be the case given the American origin of the company. The fact Japanese companies don't appear to have followed this trend could suggest that the stigma is less prevalent in Japan. This is supported by discussions with VPEC at Waseda University, who claimed that the general population don't have an issue with the concept of smart houses but that utility companies may, and that regulation is making it difficult to implement. It is thought that the comparatively positive attitude towards the digitalisation of industry in Japan, when compared with the UK, may be linked to the ageing population, as discussed in section 6.2. Given that this is causing a decline in the size of the workforce, it is thought that increased automation and digitalisation will act to balance the diminishing workforce. Since Japan is the only country with such a significantly shrinking workforce, this, perhaps combined with Japan's culture of lifetime employment providing employees with a further sense of job security, could be at the root of the apparent differing level of stigma, when compared with the UK, USA and other countries. On the other hand, although digitalisation will allow the number of jobs available to mirror the size of the workforce, it will require people to change their role and therefore the skills required. Resentment, however, was not thought to be substantial in discussions with the companies visited, however one should take into account the fact that all visits and discussion sessions were hosted by managers who may possess differing opinions to operators and lower skilled workers. This disparity between employees in positions of responsibilities, and those whom are not, is seen in the UK: "66% of UK execs believed automation could lead to job creation, while at the same time, 88% of execs said employees are worried that automation will eliminate jobs."[5] When visiting companies, it is often speaking to factory operators that the true attitudes may be gauged, thus the actuality may differ from that

[52] David Romero, Johan Stahre, Thorsten Wuest, Ovidiu Noran, Peter Bernus, Åsa Fast-Berglund, Dominic Gorecky. Towards an Operator 4.0 typology: A human-centric perspective on the fourth industrial revolution technologies. October 2016. CIE 46 ISSN 2164-8689

we have been presented with. It is assumed that the impact on the workforce, as a whole, is valued, and understood, further than the impact on the individual's role among those in positions of responsibility.

When considering the effects of digitalisation on the individual there are a number of viewpoints to account for. The simplest of these is the general distaste for change that is common across all types of change and change management. This is likely to be especially prevalent in the older generation of workers, in that it is often harder to 'teach and old dog new tricks'. As their role changes, the longer one has experienced one way of doing things, the more disruptive alterations may be. Secondly, there may be resentment, stemming from the notion that they are being replaced. This may be exacerbated by the trend for automation and robots to become more and more human like. For example, IBM have been investing is research into human emotions with the aim of applying this research to their automation and artificial intelligence systems. Both ATP and Softbank have created robots that either mimic humans or comprise the key features that we commonly associate with humans. IBM have even gone as far as using anatomic names for the robot counterparts (e.g. synapses). IBM aim not to make people feel either replaced or fearful of their artificial intelligence systems but then contradicted this when they showed how powerful Watson is by having it compete on the quiz game show 'Jeopardy!'. However, since then they have made a point of primarily advertising how their innovations are people centric. One example of this is their glasses that follow similar ideology to the concept of Operator 4.0[53]. Hitachi have been using digitalisation in similar ways to allow for continuous monitoring of individual data for personalised training. This is aiming to prevent repeat mistakes but has danger of inducing a big brother effect of constantly being watched. It may be argued that this reduces trust and may create a negative atmosphere. Daikin interestingly believe both that robots and AGVs should feel like 'part of the team', but also want to focus on creating the atmosphere where people trust that robotics is being implemented purely to help them. Thus, AGVs in the factory, which move around the shop floor constantly, have names and play music in order to 'appear more friendly', and less scary.

Looking further into the idea of Operator 4.0, and designing systems to work collaboratively with humans, automation is often described as providing support for the human operators. However, notably, this concept is most enthusiastically articulated by Fanuc, who predominantly receive orders for robots and automation systems but are not in an implementing role themselves, where resistance in this sense may be more prevalent. Omron and Hilltop were noted for

[53] David Romero, Johan Stahre, Thorsten Wuest, Ovidiu Noran, Peter Bernus, Åsa Fast-Berglund, Dominic Gorecky. Towards an Operator 4.0 typology: A human-centric perspective on the fourth industrial revolution technologies. October 2016. CIE 46 ISSN 2164-8689.

remarking that they want to use automation to make job roles easier and to allow people to do more creative roles, with Hilltop saying, "humans should do something that only humans can do". They continued on to say that it is inhumane even for humans to carry out trivial tasks, however speaking to employees indicated that this can create a lot of pressure and stress when expected to continuously be creative. Along much the same thread, Omron declared, "Taking advantage of our sophisticated development environment and unique automation technologies, we are creating conditions that make work easier and turning jobs into truly creative, people-centred activities." In contrast, Daikin has been aiming to automate the difficult tasks in particular, focussing on reducing strain on operators.

Collaborative robots are being developed to try and create a synergy between automation and human operators, particularly in the face of the ageing population, as they can help operators overcome physical difficulties at work. It is thought that this has significant potential but collaborative robots are yet to be a widespread, ubiquitous aspect of manufacturing. In many cases, robots have efficiency and safety benefits (when compared to non-collaborative robots), however there are still worries over the health and safety implications of humans working in touching distance of robots. As the ageing population affects Japan further, and these robots prove to provide monetary benefits, collaborative robots may spread across Japanese industry very quickly. Another benefit OMRON has identified of using collaborative robots is that it may attract more people to work for them, as it is seen as cutting edge to both operators and operations engineers.

While considering the impact of change on an individual level uncovers a number of sources of resistance, it can also benefit the change process. Hitachi look for someone on board with the changes desired by management and use them as an advocate in a way that aligns with Kotter's 8 steps for change, aiming to 'create a powerful guiding coalition'[54]. They use this advocate to help change attitudes among employees.

Looking back to a wider view of the impact of digitalisation on the workforce as a whole, although it is stated that automation will be used to support the human workforce, there is evidence of automation significantly decreasing the workforce requirement. For example, initially, Hilltop could run their factory for 24 hours without human intervention. As they have developed their systems, this has increased, first to 72 hours, then to 720 hours, which will clearly reduce the human resource requirement going forwards. Their factory runs 24/7, and requires few people to operate. Similarly, conveyor tracks between factories at Fanuc and AVGs at Daikin have reduced the human requirement. In addition, both Fanuc and Omron have automated

[54] Kotter, J. Leading change: Why transformation efforts fail. 1995 Harvard Business Review.

inventory management. However, Omron believe there is a limit as to how much will be automated in place of humans; they have set their goal of automation at 50% as they believe it is cheaper than 100% automation for them. If this goal continues this may justify the need for collaborative automation and harmonisation between automation and humans. This aligns with one of their primary focuses, regarding digital factories: "manpower saving by man-machine cooperative automation". Given this, they do worry about the impact of cutting the workforce, but claim that listening to employees is most important to them. The also explain that "if a robot can do their job they should be helped to look for a higher value job". It would be interesting to follow them through their increase in automation and see whether their claims of caring most about employee views are validated, or whether the importance of this is diminished by the view of managers.

It is often said that the reduction in workforce required with the implementation of digitalisation will be used to balance the declining population and skills shortage. This is supported by Hitachi's remark that they are experiencing no real resistance to automation due to replacement effects as they are struggling to find enough skilled people. However, Hilltop currently employs a significant number of people as programmers – this is a role they are trying to eliminate through automation, which will inevitably result in a substantial reduction in workforce upon achieving this ambition. It is unlikely that this will entirely balance the recruitment issues they are having, especially given that they recruit from all backgrounds, as discussed in section 6.2. Notably, the majority of their staff are young and newly trained so they are unlikely to experience mass retirement in the same way that more traditionally structured companies are, which contradicts their claim that it will all balance out to some degree. Further probing revealed they have not yet thought sufficiently about what will happen to the excess workforce created.

6.4 Digitising of human resources

Digitising (definition: converting into a digital form that can be processed by a computer) the inherently intangible skills and tasks carried out by human resources is a key challenge in the implementation of digitalisation. This is being approached and applied in a variety of ways across all industry segments.

The aging society, as discussed in section 6.2 is leading to a shortage of senior skilled workers whom are able to pass down their knowledge to subsequent generations. This intangible knowledge is at risk of being lost: a core concern for METI. Omron were found to share this concern, describing their concern that experienced, skilled workers are leaving rapidly, before young workers have had the opportunity to learn their techniques sufficiently. In discussions, they cited Toyota as an example of a company using digitalisation to tackle this issue; monitoring the techniques of machinists though sensors in machine tools for documentation and knowledge sharing purposes. Furthermore, KIT has been working on the documentation of traditional skills and knowledge through the use of sensors, able to trace the precise movements of craftsmen, with a focus on traditional Japanese industries, where skills were traditionally passed down from a single master to students through generations. At present, this is being carried out for the purpose of increasing understanding of what comprises good practice, and for knowledge sharing and training, but it was anticipated that this may be expanded in the future to enable automation of traditional industries. Similarly to the work at KIT, Tsukino Katsura has been aiming to digitalise the traditional industry of Sake brewing. However, despite substantial data collection and analysis, they struggle to replicate the sensory requirements in handling Koji for example. This limits the digitalisation they are able to achieve. Having said this, they are aiming to digitalise sufficiently such that they are able to establish a 100% automated plant in China next year, where the focus upon hand-crafting Sake is less strong than in Japan. IBM have been carrying out knowledge sharing in much the same way but with the extension in purpose in that they are digitising their knowledge so it may be transferred between sites to enable increased global integration, such that each function may be carried out in the optimal location.

Digitized skills and knowledge can be applied in multiple ways. Firstly it can be used to identify best practice and support training of new and existing employees. In this way, it could ensure that skills are not lost and support the workforce in becoming more efficient. Conversely, it may eliminate the role for the human entirely. Where the examples discussed to this point are carrying out digitisation of skills in order to transfer it back to humans, Hitachi, among other companies, are digitising skills with the intention of keeping them within the machine level, aiming for automation and skill replacement. For example, Hitachi are hoping to automate the process of scheduling by recording and machine-replicating the decision making of current managers, in order to eliminate this task from their roles. As well as reducing strain on the existing workforce this would reduce the training requirement for new employees.

There appears to be two strands of opinion on the ideal way to digitise tasks currently carried out by humans. The first approach is to observe or monitor how these tasks are currently performed and attempt to replicate the process. For example, IBM collaborates with current employees to identify good manufacturing processes to apply to their custom production machinery. Along this strand, companies are trying to make machines mimic human behaviour and operation as closely as possible. This is the case with the work carried out by KIT, as mentioned above, and at Preferred Networks, where they are working on 'one-shot learning'. This is addressing the current shortfall of artificial intelligence in that, for example, a human may be shown just one cat and is then able to recognise other cats going forwards, whereas current software techniques require perhaps a thousand images of cats to be digitised before they could recognise an unfamiliar cat. Within this line of development their ambition is to create software that mimics the human brain. In contrast, the second method seeks the benefits of the purely logical approach of programming by setting what Preferred Networks refer to as 'red lines' as opposed to a set of instructions and allowing it to derive the optimal solution. This creates opportunity for 'outside the box' thinking, giving the potential for outcomes that humans would not reach due to inherent human irrationality. This method has allowed Preferred Networks to identify novel approaches to problems. For example, in a test involving multiple cars attempting to follow a route without a collision as quickly as possible, with no intelligent link between vehicles, vehicles were observed to reverse away from junctions to allow other cars to pass before continuing on their route. Although logical, this behaviour has not been observed in the same way among human drivers. Preferred Networks offered an interesting example when considering these strands as they have successfully identified cases where human learning has superiority, as with 'one-shot learning' but also see the value in purposefully avoiding human learning characteristics in that computers may be able to offer solutions that human irrationality or societal norms lead us to discount. Thus, it follows that digitalisation may reveal innovative ways of working; inherently changing the role carried out by humans. This suggests a synergy could be achieved through strategic use of both human and computer resources in the future.

6.5 Conclusions

In conclusion, human resources, within the subject of digitalisation, introduces a number of both complexities and opportunities. Awareness of the importance of each of these is essential in effective implementation and creating strategic advantage. Complexities include: increased management requirements resulting from global collaboration; skill shortages for requirements of new and adapted job roles; resistance to automation and digitalisation as a whole; and difficulties in digitising sensory and intangible knowledge. In contrast, there are significant opportunities in: creating synergies with automation-human cooperation and collaboration; personalised training; balancing the declining workforce due to the ageing and shrinking population as well as skills shortages; and new, innovative solutions proposed by intelligent systems that may not be considered by humans as a result of inherent irrationality.

Throughout the visits, there appeared to be more awareness of the opportunities and strategic responses than the complexities to be aware of. Further research and discussion across varying levels of responsibility would give a better idea of attitudes and resistance. Despite the potential lack of regard given to attitudes, it appears there is notably less resistance and unfavourable views surrounding digitalisation in Japan, as compared to the UK and a number of other countries. This is largely due to the ageing and shrinking demographic and it could put them in a unique position to progress more rapidly, in the absence of resistance.

7 Digitalisation of offerings

7.1 Introduction

This chapter on 'digitalisation of offerings' focuses specifically on products and services produced by companies visited, that support the integration of digital technologies in manufacturing industry processes. Unlike previous sections of this report, the focus lies on the effects of products and services offered by the companies within the study, and does not consider the use of digitalisation within companies in the form of R&D or operations. Here, the offerings' effects on Japan's manufacturing industry in the short-, medium-, and long-term and the links they create between companies are analysed. An outlook on the expected development of the offerings of digitalisation solutions will derived.

The chapter is divided into six sections covering:

- The relevance of IoT, big data and cyber-physical systems – this highlights where the companies visited in Japan fit into these areas
- A discussion on the advancement of digitalisation of offerings currently seen in Japan and the challenges of lack of know-how, which is influencing the way in which digitalisation is being implemented
- A discussion on the lack of transferability of solutions to digitalisation and therefore the need for intermediate companies or consultancies to void this gap
- A discussion on the government's influence on the offerings of companies and interest in the healthcare secto
- A discussion on the lack of and need for an ecosystem to support digitalisation
- A summary of the findings from this chapter, highlighting key outcomes and recommendations

7.2 Internet of Things (IoT), Big Data, and Cyber-Physical Systems

Companies' offerings in IoT, Big Data and Cyber-Physical Systems are closely linked and any application within a manufacturing context spans at least two of these fields. Although they are closely related, these offerings in the different fields require different skills and know-how at the current state of technology. Over the course of this project, it was observed that there is no platform or ecosystem currently established which effectively combines the use of sensors from different suppliers with data analytics solutions to create a "smart" system. Such a system would form a co-engineered interacting network of physical and computational components. Even within the field of Big Data two distinct approaches are used. One is cloud computing were all data analysis is conducted within the the cloud network. IBM is a main supporter of this technology. Other companies pursue the technology

CASE STUDY

PREFERRED NETWORKS

Preferred Networks (PFN) describe themselves as the product of combining Deep Learning with the Industrial Internet of Things (IIoT). Their offerings focus on providing software for industrial devices that replaces traditional control systems with adaptive systems powered by machine learning. Such systems allow PFN's customers to automate production processes without rewriting control software whenever a new product or task is presented.

Instead, the adaptive systems use Deep Reinforcement Learning techniques to let industrial devices figure out how best to complete a new task on their own, by trialling potential solutions over a short period of time.

For example, PFN offers a system to control a pick and place robot which works with a vision system to move randomly-oriented, assorted items out of a container into a production line. The system does not need to be manually programmed to recognise the orientation of items as it learns the best approach for situations it is presented with by trial and error.

of edge computing which is seen as a method to optimise cloud computing. Data analysis is conducted in local processing machines and results are shared via the cloud. This approach is taken by Prefered Networks which sees the main advantages in cost, latency and privacy or security of information.

The companies analyzed as part of this research were found to specialize in a subset of IoT, Big Data and Cyber-Physical Systems. As a whole, the digitalisation of industry in Japan covered each of the areas with expertise being created in all fields. A representation of where the expertise of the individual companies lies can be seen in Figure 7-1.

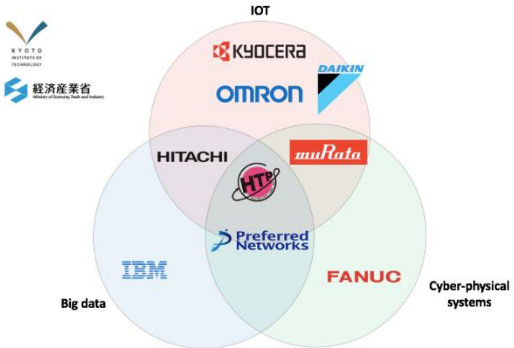

Figure 7-1 Expertise of Companies

The following companies outlined are those that were visited and whose offerings were considered to be significantly advancing the digitalisation of manufacturing movement.

IBM

IBM's key offering that advances the digitalisation of manufacturing is Watson; a cognitive computing platform used for many applications including to optimise plant operations. IBM have recently shifted from a 100% focus on hardware components to now a 30% investment in cognitive computing efforts in response to the growing demand for digital manufacturing worldwide. They explain that “We are becoming a Cognitive Solutions and Cloud Platform company”. It is apparent that the term 'Industry 4.0' effectively coined by Germany is recognised by different names across companies and countries. For example, IBM have seen industry has progress through 3 eras: the tabulating systems era, programmable systems era and now cognitive computing era. The cognitive computing era acknowledges the increased use of deep learning algorithms to optimise the utility of the big data that is continuously created in any manufacturing setting. By focusing on platform technology, IBM aims to be the industry leader by offering a ubiquitous solution, as opposed to offering subsystem solutions similar to Preferred Networks (discussed below). Increased computing in manufacturing settings will require greater processing power; IBM continue to develop the hardware components that are required for processing Big Data such as the new SyNAPSE chip, using the human brain for inspiration. In this way, their primary technology is shifting to

CASE STUDY

FANUC - COBOTS

FANUC, the world’s largest robotics manufacturer, produces robots to aid manufacturers’ production processes. Collaborative robots (‘cobots’) are a recent cyber-physical product offering, which is slowly becoming more dominant in manufacturing environments.

Cobots, however, are seen as a controversial tool as robots have previously been used to remove humans from the production line during automation in the 3rd industrial revolution. Furthermore, the markets for these robots are limited, as sectors such as chemical and food production see humans as contaminants, so would have no need for the collaborative technology. For now, cobots are seen as a niche offering that may be more useful in the future when customisation becomes more important in product and service offerings.

With Japan’s ageing population, collaborative robots will be an important asset to work alongside humans who in the near future may not be able to perform physically strenuous tasks by themselves. An example of the use of cobots, seen at the FANUC site, is installing spare tires in automotive manufacturing, see below.

become the enabling technology. They focus upon client engagement and helping clients to find the most insightful parts of their own data.

Preferred Networks

Preferred Networks integrate deep learning and reinforcement learning algorithms within specific hardware applications. PFN work closely with companies including FANUC, Toyota and NTT with regards to improving the efficiency of their production operations. They are directly contributing to the advancement of digitalisation of manufacturing by focusing on optimisation of industrial devices.

FANUC

Fanuc is a key driver of the global movement towards digitalisation of manufacturing. The key offerings focus on increasing intelligence of industrial robots; particularly their development of collaborative robots - incorporating collision detection, their development of learning robots - incorporating reinforcement learning algorithms to optimise operation, and their improving of intelligent sensors such as 3D vision systems and force sensors. Fanuc's Zero Downtime project is pursued in collaboration with PfN with the aim of optimising preventative maintenance by increased monitoring of industrial devices. Their zero downtime technology is being trialled in the UK, and data is shared with approximately 10,000 robots in the US; FANUC do analysis to predict breakdowns in advance, by pooling this data in large data centres. Furthermore, the FIELD technology platform being developed (ready for March 2018 release) aims to unify all equipment in the plant under one monitoring platform, similar to IBM's Watson vision. FIELD, the acronym naming their open IoT system, stands for the FANUC Intelligent Edge and Link Drive System. This utilises edge heavy computing, which was justified because they believe that sensitive information 'can't be compromised' by other technologies.

VPEC

VPEC aims to improve the efficiency of power distribution at a national level. Therefore their offerings do not directly advance the digitalisation of manufacturing but will enable efficient use of energy which will be increasingly important when digitalisation is widespread.

Hitachi

Hitachi describe themselves as 'the best in the world at combining Industrial Assets and Intelligent Services', referring to the industrial IoT. Hitachi Digital Solutions was the part of the conglomerate visited by the research team, a group consisting of data analysts and consultants who work with customers to co-create digital solutions. Examples of their work include bespoke solutions surrounding implementing IoT, innovating with data and analytics, and generally accelerating the digital transformation of external companies. They have developed an

CASE STUDY
IBM - WATSON

IBM's Watson is a cognitive computing platform, commercially available for applications in commerce, education, finance services, health, marketing, HR, supply chain and IoT manufacturing. Watson was initially built in 2005 to meet the challenge of playing Jeopardy! (the American game show).

In industrial applications, the Watson platform can analyse real time and historical operation data across a range of industrial applications and provide descriptive and predictive outputs.

This ability to provide prescriptive outputs reduces dependency on human judgement and provides solutions based on a larger, digitally stored wealth of knowledge. Itis a key feature distinguishing Watson from analytical tools.

Watson enables improved quality, operations, and maintenance in industry, enhancing value obtained from production assets and processes. A unique feature is the aim for a single platform to ubiquitously analyse all sections of the plant operations.

The platform focuses on maximising efficiency of manual operators as opposed to replacing operators with automation. By monitoring practises, the goal is to enable every operator to work at a uniformly optimised rate.

IoT platform called Lumada[55], which they placed a strong emphasis upon. Its slogan is 'Illuminate your Data and Accelerate your IoT Journey'. The platform allows them to use a collection of repeatable IoT 'Building blocks', providing a modular, custom system for the customer, and focussing on working with the customer to get the best solution. Using the Lumada platform, they bring together Artificial Intelligence, Analytics and Co-creation to generate new business ideas from various data streams. This provides new value for both Hitachi and the external companies to whom they provide this service (70-80% of this group's work is for external companies).

In addition to Lumada, Hitachi have placed focus upon the importance of being able to transfer know-how using AI. They highlighted the need for solutions to problems caused by Japan's ageing population. They often do this in a three-stage process. First they simply set up their software to watch an operator by recording their decisions; using AI this builds a platform that tries to mimic the operator, and can be used to help the operator make said decisions. By watching how the operator disagrees with the model it gets more and more intelligent until the system is helping the operator make better decisions than the operator working alone. Eventfully it can be used to make these decisions automatically.

Additional AI examples were provided, such as a vision system linked with AI to notice operators making out of the ordinary movements, which is used to control product quality, as well as their cyber physical system offering of 'EMIEW', a concierge robot, which has been deployed at one of Tokyo's airports. Hitachi Digital Solutions explain that AI is a key driver for companies' transformations. They believe that this is their competitive advantage, combined with their strength in hardware. More than 50% of the parts used in the digital solutions are sourced from Hitachi themselves, something they believe to be of competitive advantage. Their vertical integration and the associated know-how could help them in their competition against companies such as IBM with their Watson offering (see above). They also explained that they believe GE to be a key competitor, since they led the way with Predix, as well as many startups with innovative offerings. Additionally, they believe that the next large challenge is digitalising the whole supply chain – and this is what their offerings need to work towards.

METI

Whilst METI are not directly offering products for digitalisation, they are defining the route to digitalisation for Japan and Japanese companies. See section 8 for more information on this area.

[55] Hitachi Vantara's Lumada, https://www.hitachivantara.com/en-us/products/internet-of-things/lumada.html, accessed 24th October 2017

OMRON

OMRON is reacting to the challenge of global competition in the IoT sector by continuing to develop control devices for factory automation. It was explained that this business activity, the Industrial Automation Business section (IAB), accounts for 42% of OMRON's net sales, it's slogan being 'bringing innovation to manufacturing by automation'. OMRON explained that their endeavours in IoT Automation have been led by the 'future prediction theory' by OMRON's founder, and they believe that this is what puts them a step ahead. This theory is summarised by the acronym 'SINIC': Seed - Innovation to Need - Impetus Cycle evolution[56]. This theory has been the 'compass' for OMRON's management for decades; it seeks to predict the future, and the changing technological demands of society. However, despite making many devices for factory automation, many of their products are not IoT products, and this concerns them – they want almost all of their devices to be online by 2020. It was explained that OMRON sensors, such as a MEMs flow sensor, can be improved by making it an IoT device. This would allow OMRON to pool all data from all these sensors to improve them, one goal being achieving predictive maintenance. Their future vision is to better use such data, and connect everything with IoT. They hope to encourage customers to be better at collecting data, so that they can share and use it together, utilising open innovation to improve their product offerings.

In an additional part of their business, OMRON explained that they offer tours of its factory to show other companies what their systems can do. They are considering the option of progressing this to a 4.0 service model. They explained that there are many small manufacturing companies in Japan, and they would like to help them.

Hilltop

Hilltop focuses on creating products and services that enable the development of smart factories and advances the digitalisation of manufacturing in general. In particular their prioritization of developing sensors which fill gaps in the market (such as viscosity sensors) highlights the national drive towards saturating the market with sensors in a bid to move towards IoT.

In addition, Hilltop are also moving towards a service-based all-in-one solution for SMEs, to help them implement IoT systems. This was described as being like 'plug and play'; the implementation is all done for the SME, including the programming, data transfer and interface, so that the customer can then analyse the data with ease. This is a key advantage in the minds of smaller companies, who lack the resources, to design their own systems from scratch. Hilltop see this digital service as being the largest revenue stream in the future and are currently

[56]OMRON's SINIC theory, https://www.omron.com/about/principles/sinic/, accessed 24th October 2017

using demonstrations, such as their fully IoT-enabled Lego factory, at expositions to show off their skills. A key emphasis here was placed on the benefit of being able to test their own service on themselves and their own factories first; once IoT has been successful at Hilltop, they can look to sell the solution to other similar sized companies in the area. Their own Smart Factory is being launched internally at current.

Hilltop explained that they want to develop most of the systems themselves, but they are aware that they need to ensure their systems are compatible with what proves to be the largest communications/ IoT standard, although they are unclear what this is as of yet. In this endeavour, as well as building demonstrators and prototypes, Hilltop have already started approaching SMEs. They have been starting to help them with Big Data projects and IoT product development in order to gain knowledge and insights into the marketplace. This focus upon working with small scale firms highlights the fact that the digitalisation movement is progressing beyond the advancement of conglomerate firms and onto the advancement of SMEs.

It will be interesting to watch Hilltop's progression over the coming years. With many exciting digital initiatives, such as the IoT solutions service and automated CAD to CNC machine code (g-code) software development, as well as plans for an expanded design consultancy, their business model has many different parts to it. Hilltop is certainly an innovative company when it comes to the digitalisation of its offerings: employees are encouraged to pursue their own innovations and then see if there is a feasible business model for these which can be pursued. Thus, the digitalisation-related offerings from Hilltop in the future may be extremely wide ranging. This is something which could definitely be a strength, but potentially also a weakness, if initiatives are not prioritised correctly and they could fail due to lack of resources.

MuRata

MuRata directly advances digitalisation of manufacturing by providing new value through developing sensors, advanced telecommunications technology and miniaturization of electrical components, primarily of ceramic capacitors. These technologies are integral when considering the increased demand for IoT systems. In addition, MuRata has developed numerous examples of robotic, Industry 4.0 related, technology, which they use as demonstrators in their new Open Innovation Centre.

Kyocera

Kyocera's ceramic components used in electrical devices, while not directly advancing digitalisation of manufacturing, may be considered key enabling technologies for the advancement as they are an integral component of digital devices.

7.3 Awareness of digitalisation offerings in Japanese manufacturing companies

Although there is a large sense of 'hype' about digitalisation in Europe and the United States, when it comes to implementation in Japan, a lack of awareness and deeper understanding of the field is seen. Multiple companies [ref Hilltop, Omron] emphasized the need for an implementation service which goes beyond offering the Japanese manufacturing industry the products needed for digitalisation, and this is something Hilltop aspire to provide. This creates a business case for companies specializing in consultancy services or offerings that combine products and services. Fig 7-1 in section 7.2 shows that many companies focus on creating expertise in combining different products by delivering an integration service. Currently, the offerings are found to have a strong tendency to move to increasingly service-oriented systems, as discussed in section 3.1.

A potential reason found for the lack of extensive knowledge in the field of digitalisation lies in the small size of many manufacturing companies in Japan. The small size limits the resources that can be dedicated to monitor future technologies. This is expected to be a lasting phenomenon in Japan since the Ministry of Economy, Trade and Industry (METI) promotes small scale manufacturing companies. In the near future, the need for digital service offerings could increase as SMEs seek digital expertise or off the shelf digital solutions.

It was also found that knowledge of digitalisation is predominantly found extensively in large companies in Japan. This knowledge is in line with a sense of urgency as competitors in Germany and the US showcase more advanced implementations. As such, large companies such as Daikin have now started to include sensors in the designs of their products to join the IoT trend. Offerings extending beyond the readily available knowledge in digitalisation were found to be developed by smaller companies - often startups - such as Preferred Networks which focus on developing applications from state-of-the art research.

While the market for digitalisation offerings generally has low barriers to entry and a wide diversity of solutions and platforms, it is still an immature market. One of the primary barriers to a fast and large scale adoption of digitalisation across the whole manufacturing industry is the lack of transferability of solutions. So far, digitalised systems are custom-made and unique to their applications. The lack of smart solutions and standardized approaches to digitalisation, combined with the lack of key players which are yet to emerge, has led to an unstable ecosystem.

7.4 Lack of transferability of solutions

The current state of cognitive network technology limits the application of cyber-physical systems. Solutions tend to be application specific and unique to each customer. This issue manifests itself, for example, in a trained network (e.g. for a pick and place application with a robotic arm) which cannot be transferred to a slightly altered physical system (see the Preferred Networks case study). Research (see section 3) is being conducted into improving transferability, but companies such as Preferred Networks expect that it will be around another ten years before such transferability can be achieved. It is therefore expected that the market for consultancies which design and implement unique solutions will be stable or increasing over the next decade. Companies of various sizes, from Hilltop to Hitachi, are aspiring to provide this level of functionality.

The furthest progress along the path of implementing a standard platform that can be used across various applications and fields beyond manufacturing has been made by IBM with its Watson artificial intelligence platform. By partnering with large corporations worldwide IBM is attempting to establish itself as the standard for industry. In the current state, however, the platform needs application-specific program interfaces in order to work, i.e. unique solutions. The technology not being easily transferable implies that any solution or offering is still only as good as the human being designing it. Input variables, objectives and decisions on sensor design are still largely decided by experts. Solutions which go beyond and skip some of these manual steps are still in the research phase.

7.5 Funding for digitalisation

Advanced Telecommunications Research (ATR) Institute International are a 60% government funded (40% private) research centre in Kyoto and one of their specific objectives is to advance robotics technology through their offerings. It is interesting to note their large focus on healthcare applications given that many other companies visited (such as PFN and IBM) have moved away from this sector to manufacturing technologies (which are seen as having a greater profitability). ATR's focus on digitalisation for the healthcare sector is due in part to the influence of government funding upon the research areas chosen. The Japanese government needs a focus on research in this area as the country's aging population requires access to better healthcare oriented technologies. As noted by ASTEM, the government may also have interest in this area as they attempt to appeal to the large voting block made up of their aging population. In summary, it was observed that healthcare offerings are increasingly backed by public funding while manufacturing offerings tend to be more privately funded. Nevertheless, both sectors show an overlap of offerings. The ageing population has a major impact on the manufacturing industry, as discussed in section 6. As such, there is a focus in both sectors on offerings of human-machine interfaces. ATR uses its Keihanna ATR fund to financially support multiple spin-offs who wish to commercialise their research findings[57] in the field of humanoid robots. The safe interaction between robots and humans is a large field of interest, and this is demonstrated by research at FANUC with their first collaborative robot offerings being on the market (see FANUC case study). The implementation of a large-scale robotic workforce to support or replace human workers, potentially working 24/7, will have major impacts on the supportive functions surrounding the manufacturing industry. The next chapter will therefore analyse the need for a supportive ecosystem which makes digitalisation offerings in manufacturing sustainable and effective.

7.6 Supportive ecosystems

The increasing implementation of robotics within manufacturing has led to a notable change in the nature of factories. Lights-off, fully-automated factories, such as the FANUC manufacturing facilities, operate with minimal human interaction. This creates a need for faster, more robust, and more complex communication networks to manage manufacturing tasks in real-time. Multiple companies have picked up on this gap and focus heavily on improving telecommunication and information systems. Kyocera Communications Inc., for example, offers a product service system that helps manufacturing companies to have reliable and robust communication infrastructure.

For fully automated manufacturing, there is no need to stop production during the night or on holidays, which leads to a change in the power requirements of the manufacturing industry and the offerings from the energy industry. For example, Hilltop's factories run 24/7. After the change in Japan's energy policy after the Fukushima Daiichi nuclear disaster in 2011 - which moved the national energy supply away from nuclear and required a rapid uptake of renewable energy sources - a need for a new grid design was established. VPEC and Kyocera are examples of firms working on energy management systems and stable decentralized power networks that can support the move to increased automation within this new energy climate.

7.7 Conclusion

The offerings which advance the digitalisation of manufacturing in Japan are still very fragmented. The market is developing quickly, with companies approaching the problems from many different angles but with the common goal of developing a standard platform or ecosystem for digitalisation. Until these issues of transferability of offerings are solved, the market for consulting services will continue to increase.

Although some companies, and METI, mentioned that the attempts at standardization are being made as a collaborative effort, it was found that existing solutions are competing with each other. It is expected that being able to provide standardised solutions across the

[57] *Note: There are currently 6 such companies: Telenoid Planning Inc, Blue Innovation CO.,Ltd, Yukai Engineering Ltd, FIT CO., Ltd, Supreme System Co., Ktd and ATR-Incubator Ltd.*

manufacturing industry will be a major breakthrough in the development and uptake of digitalisation on a larger scale. The company or nation to solve this problem first will become the key player on the market due a drastic reduction in lead time, costs and network interaction issues. This is why many companies are aspiring, and competing, to achieve this goal.

Japan is specifically investing in digitalisation efforts that help the manufacturing industry to cope with the ageing population. Collaborative robots and facilitating technologies will move a significant portion of the human workforce into knowledge work areas, thereby increasing the maximum working age and offsetting a skills shortage, if education and training in these areas can keep up with these demands.

Individual companies have started to realize that offerings in IoT, Big Data, and Cyber-Physical systems cannot be realized in isolation, and that the industry as a whole has to create about a supportive ecosystem for the digitalisation of manufacturing to be completed effectively.

8 Industrial policy

8.1 Introduction

The digitalisation of manufacturing is forming a revolution that is affecting whole value chains and whole economies, both nationally and internationally. Thus, it is a subject which is of key concern to countries' industrial policies, and naturally is of particularly high importance to the policy makers of countries such as Japan, where manufacturing accounts for a high proportion (approximately 20%[58]) of their Gross Domestic Product (GDP). The role of government in business in Japan has traditionally been seen as a positive influence, and a constructive, empowering relationship has been known to exist between the two sides. The U.S. Library of Congress explains that the perception of government in Japan is grounded in the country's roots of Confucianism, leading to the view of industry and government as collaborators, striving towards the national consensus that Japan must succeed as an economic power. This is known to instil the duty of all Japanese citizens to make sacrifices for this national goal. Discussions with METI informed the research that their method of influence into Japan's industry was by writing papers and distributing information. The key parts of this were found to be the production of an annual white paper discussing relevant issues, as well as the collecting, synthesising and distributing of use cases, which are essentially case studies of digitalisation in action, to facilitate knowledge sharing.

This chapter investigates the role of government, specifically Japan's Ministry for Economy, Trade and Industry (METI), in leading and facilitating progress within manufacturing digitalisation. Research was undertaken through discussion with leaders at METI, including their Head of IoT, and analysis of their white papers and journals, combined with discussions with industrial players surrounding government involvement.

8.2 Awareness of global trends: why Japan must compete

The digitalisation of manufacturing is occurring across the globe. It is therefore to be expected that, in today's age of easy communication and globalisation, countries look to one another for guidance and benchmarking in their ventures, as well as collaboration to enable mutual advancement. It was found that Japan's policy makers, and indeed their industrial counterparts, have been looking to manufacturing powers such as Germany and the United States. These countries have given them both inspiration and fear, combining in a sense of urgency to 'keep up' and maintain their industrial competitiveness in the digital age. An article in METI's journal in 2015[59] highlighted the importance of Germany's movements in this space,

[58] World bank national accounts data, https://data.worldbank.org/country/japan , accessed 12th October 2017

[59] METI journal, 2015, http://www.meti.go.jp/english/publications/pdf/journal2015_05a.pdf, accessed 12th October 2017.

with their world leading 'Industrie 4.0' spanning across industry and government. In this discussion, Professor Nishioka urged that Japan needed to construct 'connected factories' by 'leveraging Japan's own strengths' to stay competitive. Conversations with METI informed the research group that the new 2017 white paper, which is brought out annually and was being described to the group before it's English release later in the year, was influenced by ideas from papers from France, Germany and Switzerland. Discussions with METI also revealed the need for an international standardisation approach, for which there has been a proposal for a Unified Reference Model.

8.3 Awareness of national trends: why Japan needs digitalisation

A key theme discovered throughout this research was the importance of using digitalisation of manufacturing to solve, or to aid, broader national issues, both industrial and social. The most frequently discussed of these, in literature as well as both METI and company discussions, was the issues of the ageing population. This was a described as a serious national problem by the vast majority of the companies visited, while METI echoed the sentiment that automation and digitalisation were vital in addressing the social problem of their ageing population. Thus, in terms of policy, digitalisation is seen as an issue that spans further than the boundaries of merely improving manufacturing and industry. It affects Japan's ability to simply exist as an economic power, since without it, due to rapidly declining human resources, they may lack the labour force to continue current manual, human-centred operations. Interestingly, digitalisation was therefore seen to be a positive power, rather than the threat to jobs which creates a real problem in many economies, including the UK's. METI also explained that their new 2017 white paper discusses actions for addressing the national skills issue of transferring skills from the older generation to the younger generation, by emphasising the importance of visualising skills. This allows knowledge to move from an intangible state, inside the brains of certain operators, to a more tangible one. Conversations surrounding the 2017 Japanese white paper informed that developing HR within digitalisation was the "most important" issue.

Digitalisation is also seen by policy makers as a potential solution for Japan's recent productivity issues. METI discussions informed the research group that Japanese ROE is very low compared to that of the United States, and this is something which they are concerned about. Additionally, the discussion on the new 2017 white paper, which has not yet been released in English, explained that labour productivity is a key concern for Japanese policy makers and the Japanese economy. Whilst this is in many ways surprising, it is in fact evident that Japan has fallen in the productivity world rankings. Japan was historically 2nd or 3rd in the world in the 1990s-2000s, however suffered a plummet to 14th

in 2005. They have not been able to recover from this yet, stabilising at around 10th-11th.[60] Japan's policy makers are hoping to leverage Japan's skills in areas such as robotics, with their Robot Revolution Initiative to regain their position as a global productivity leader. Additionally, METI are seeking develop new norms surrounding more collaboration, open innovation and data sharing environments, which are not historically natural in Japan. The Head of IoT at METI explained that initiatives were being drawn out for regulatory reform surrounding data ownership, however some companies were not very open to this, at risk of losing full control of their own data.

The previous finding further connects to the emphasis placed by METI upon the need for an ecosystem to share data. Potential examples for this were found at IBM and Hitachi, as discussed in section 7.6. METI explained that they saw it as crucial that data was shared, since one company may find data unimportant, but another may be able to use the data to create a new business model, advancing Japan's economy by looking with a more holistic view. METI further explained that in addition to this, they are investing budget into funding the work of data analysts, since they reported that 26% more data is being collected when compared to only a year ago, however companies are unsure how to use it. This is an area which METI sees as vital, and which they are hoping to help develop.

In addition to the national trends discussed, METI's new white paper also highlights the statistic that 10% of manufacturing is returning to Japan from areas such as China and Hong Kong, due to labour cost increases in those regions. This, combined with analysis of stock prices and exchange rates being highly volatile, which was seen to demonstrate the likelihood of change in the global economy, highlights the importance of acting now to move Japan's manufacturing processes into the digital age.

8.4 Society 5.0 and Connected Industries: the new buzzwords

The key concept discussed by METI during the meeting was that of Connected Industries (CI), falling within their proposals for a new, more connected society, termed 'Society 5.0'. Society 5.0 is a new movement brought forward by Japan, which is set to be further revealed in their white paper. Naturally, it has many undertones stemming from Germany's Industrie 4.0, however Society 5.0 focusses upon digitalisation and connectivity in broader, cross-society sense, rather than industry alone. The technologies highlighted in the preliminary reports on Society 5.0 include references to Big Data analytics, AI and

[60] 2017 METI white paper on digitalisation, shared with the group during visit July 2017, not yet published in English

Cyber Physical Systems, alongside the clear elements of IoT within Connected industry and society.[61] It was explained that the 3 pillars of Society 5.0 are:

1. New Digital Society
2. Multilevel Cooperation
3. Human Resource Development

Within these pillars, the themes found from analysis of global and national issues can be clearly seen to be being addressed.

'Connected Industries' is a term that falls within Society 5.0, forming a link between society and technology, which focuses upon the industrial side of digitalisation and connectivity. It was described by METI leaders as "the new kaizen", demonstrating its crucial importance to Japanese industry. The focus on this term in the discussions held with METI's Head of IoT followed on from the METI journal in 2015, which introduces the importance of 'Japanese Factories Connected Together'[62]. Both highlighted the shift of manufacturing from developing countries to developed ones such as Japan, who demonstrate skill in production technology and IT utilisation. Thus, it was found that this is an area which has been on the radar of Japan's policy makers for a few years, but which is gaining more focus and formalisation. 'Connected Industries' is an umbrella term for the connectivity of humans, machines, plants and organisations. The connectivity of organisations links to discussions of platforms and ecosystems mentioned previously, while also linking to Japan's Industrial Value Chain Initiative (IVI)[63], which focuses on facilitating and encouraging collaboration amongst companies. Of the companies investigated in this research, Daikin referred to the positive experience of being part of the IVI. The concept of Connected Industries also aligns with Japan's push towards helping the success of SMEs. One goal of 'Connected Industries' is to expand the range of fields in which SMEs can play an active role. Conversations at METI concluded that support for SMEs producing IoT related products and technologies is very important, with the Head of IoT explaining that this needed to be expanded further in Japan. This sentiment was further echoed at the group's visit to Hilltop. In line with this point, a further emphasis was placed upon small lot production and new business models promoting Japanese smart manufacturing.

[61] Japan's Society 5.0 going beyond Industry 4.0, https://www.japanindustrynews.com/2017/08/japans-society-5-0-going-beyond-industry-4-0/, accessed 12th October 2017.
[62] METI journal, 2015, http://www.meti.go.jp/english/publications/pdf/journal2015_05a.pdf
[63] Japan's Industrial Value Chain Initiative, https://iv-i.org/wp/en/what-is-ivi/ , accessed 12th October 2017.

8.5 'Sectorial' and 'Common' approaches

The meeting held with METI explained the areas in which METI will be focussing over the coming months and years. The department has divided these into what have been called 'Sectorial Approaches' and 'Common Approaches'.

Sectorial Approaches show which sectors will be focussed upon; these are the sectors Japan predicts will bring large scale economic benefits to the nation's economy, if invested in further. The 4 approaches are as follows:

1. Smart manufacturing (this was explained to be the most important concept)
2. Intelligent Transport Systems (ITS)
3. Robots and Drones
4. Biotechnology and Healthcare.

Common Approaches show which areas and technologies are crucial to develop in order for Japan's manufacturing industry to exist, and even to strive to lead, in the digital age. These 'approaches' span the breadth of industry and are relevant and important in a vast range of applications. The 6 approaches are as follows:

1. Data use
2. IT skills and training
3. Cyber-security
4. Artificial Intelligence
5. Intellectual Property
6. Standardisation.

As mentioned in numerous of the previous chapters, these are all areas which were highlighted in the industrial visits held within the trip. Thus, it seems that the government and industry are aligned in what they strive to achieve for the country, but also in what they believe are hurdles that need to be overcome in the process. This should bode well for the future of Japan's industry, if indeed these areas are tackled with success.

8.6 Industrial involvement

In addition to discussions held with METI, many of the companies visited were also asked about their feelings towards, or connections with, government industrial policy. The overall finding of this part of the research was that, despite METI explaining that 2000-3000 companies were involved in the formation of their annual white paper, there still exists a gap between government initiatives and company reactions or responses. The individuals interviewed at the majority of the companies had no particular comment to make upon government relations, and were often unaware of the initiatives and papers being launched. Companies were asked if they were affected by, or indeed were able to affect, government industrial policy, however the majority felt there was little relevance to their business going forward.

Individuals at Omron, a large Japanese manufacturing power, and a member of the Industrial Value Chain Initiative, explained that they would do “what they want”, regardless of government movements. They believed that they would rather the government had a clearer vision, perhaps like the approaches detailed previously, which are in the process of being rolled out. Omron also had extensive knowledge of the policies of Germany and the U.S., suggesting that international powers were having more affect upon them than their own parent country. It was explained that, in their opinion, Omron did not have particularly strong connections with the government when compared to companies such as Hitachi and Fujitsu, who are “historically strong” manufacturers. They did however explain that they would like more involvement, and that in the past Omron have worked together with these companies on areas such as IoT, and have gone to the government together for discussions.

A more negative narrative was found at Fanuc, who explained that they would ‘make their own mind up’, and dismissed any further comments on policy. When Daikin were questioned on the same topic, however, they described being part of an ‘IoT consortium’, the IVI, and explained that the government always helped them by providing funds and “an environment to make new things”. Hilltop echoed Daikin by describing a case where, 2 years ago, the government started to push Smart Factories, with initiatives such as funding and putting on exhibitions.

The most highly publicly funded organisation visited as part of this research was ATR, the Advanced Telecommunications Research Institute International, since it is a research centre funded by both public funding organisations, such as METI, and private companies and stockholders. Through ATR the government funds research with the intention of future commercialisation, with cutting edge discoveries in neuroscience, communication and robotics. Currently, there appeared to be a gap between this research and the businesses who could make meaningful use of discoveries, as, when questioned, little information was given surrounding live commercial applications. It will remain to be seen whether this research translates to commercial activities effectively, as it is an area which ATR are focussing upon.

8.7 Conclusion: Industrial policy

To conclude, it is clear that Japanese policy makers at METI are well informed about aspects of digitalisation, and the trends occurring both nationally and internationally that relate to this industrial revolution. The digitalisation of the whole of society, via ‘Society 5.0’, and of industry specifically, via ‘Connected Industries (CI)’, is clearly of high importance to the Japanese government, and to Japan as a country, as they seek to gain competitive advantage and aid some of their national issues, such as productivity drops and their aging population. Within this focus, it is evident that they place the utmost focus upon their human resource strategy surrounding industrial digitalisation. The flaw in all of this at the moment, however, seems to be that METI's actions are not always being effectively translated to the company levels, which would enable companies to benefit from government activity. Whilst some companies were appreciative of government actions, other seemed unaware, or even unaffected, by the support received. Their new approaches, via both sectorial and common approaches, may enable a more 'hands on' approach, which could be seen as a positive by many of the companies visited.

9 Conclusions

The Overseas Research Project 2017 set out with two complimentary aims:

1. To develop an understanding of the state of the digitalisation of manufacturing in Japan, allowing comparison with other developed industrial economies.
2. To provide an experience for the manufacturing engineering students of the University of Cambridge to plan, fundraise and execute a research project on a contemporary issue of manufacturing.

On reflection, 18 months after the project was first conceived, it can be stated that both objectives were fully met.

Looking at the digitalisation of manufacturing in Japan, clearly the analysis that has been conducted has yielded conclusions for different parts of the value chain about the state of play versus the rest of the world. These have been explored in detail throughout the report. However, reflecting on both a cross-sector and cross-value chain basis, there are four main conclusions that can be drawn.

Firstly, Japan is fully aware of the potential benefits of early adoption of digitalisation techniques and the pitfalls that may befall companies who are too slow to adopt them. This is encapsulated by policy makers, but also expressed at a company level. Throughout discussions, Germany were seen as being the current "market leaders" in the ideas competition of digitalisation, and the USA were seen to be following, with their current wealth of digital companies. It does appear that a disconnect does exist though between policy makers and industry, dependent on the type of company interviewed, however METI are undertaking interesting initiatives to resolve this and aid the digital industrial revolution in Japan.

Secondly, throughout all areas of the value chain, collaboration and further development of data standards is essential to fast forward progress. Collaboration may take the form of eco systems or direct company partnerships. Currently, digitalisation will progress slower through the industrial world than the lean revolution because its solutions are generally bespoke, and guiding principles not as easily moved between industries and value chain sections as lean principles were. However, a key area to watch within collaboration is establishing where value is, and ensuring that operational companies do not cede the value of their data to those companies who propose solutions. Collaboration and open innovation are clearly vital, but will involve a paradigm shift for

Japan, where industry is traditionally much more closed. In addition, tied to this learning, and the concept of ecosystems, is the need for a recognised IoT platform that is common place and transferrable across companies. This was highlighted in many of the discussions held, and is something that companies such as IBM and Hitachi are seeking to compete in.

Thirdly, implementation, as with all goliath changes in business models and operations, requires a tricky balancing act to be performed between the benefits of innovating and staying ahead of the competition, and establishing a compelling business need for the innovation so as not to invest in "white elephants". The hype around digitalisation should not cloud reasonable judgements, and the importance of digitalisation should not be confused with the concept that every digital project is economically sensible, and it should not be assumed that every project is applicable for every industry. Due care and attention needs to be used to establish priority projects, as well as to cater for quick wins to ensure that change is managed correctly.

Finally, digitalisation is tightly linked to the ageing population found in Japan. This is a demographic problem that is particularly acute in Japan, but has relevance to most developed economies. Digitalisation can help to transfer knowledge, increase productivity so as to reduce the requirement for the number of workers, and aid the achievement of a host of other benefits. These are benefits that the Japanese government hope that digitalisation and automation can bring in order to help both industry and society as a whole.

The overseas research project 2017 would like to take this opportunity to thank all the organisations and individuals involved with organising the research project, both at the Institute for Manufacturing in Cambridge, and throughout Japan. The organisation, trip and research contained in this project has been an incredible opportunity for the group and has enabled valuable learnings, both on the academic and professional levels, for all of the students involved.

This report was contributed to by all 23 members of ORP 2017 (all Masters of manufacturing engineering students at the University of Cambridge, graduating in 2017). The final compilation and editing was done by Zoscha Partos, Jordan Salmon and Edward Holt.

Appendix A. Organisation summary paragraphs

Advanced Telecommunications Research Institute – ATR is a mixed public and private institution, based in Kansai science city outside of Kyoto. It aims to promote pioneering and innovative research on information and communication-related fields with global collaboration among industry, academia and government. Additionally, it strives to contribute to a wide variety of welfare of society and humanity by outstanding achievements and to lead growth of Kansai Science City as a centre of excellence in the world. The research presented to the ORP was based around robotics, sleep and machine learning. - http://www.atr.jp/index_e.html

ASTEM - ASTEM is the Advanced Science, Technology and Management Research Institute of Kyoto, and is designed to expand the economic circle of Kyoto, through promotion of regional industry, science and technology. It was established in 1988. They have established a network with industry, academia and public involvement in various R&D and business projects. In addition, they provide support for developing technology-based new businesses across a number of fields, including software, nanotechnology, biotechnology and mechanics. Recent projects undertaken include: research into an application framework for a broadband network environment; consortium R&D projects for regional revitalisation, in collaboration with the Ministry of Economy, Trade and Industry; and development of a bus location system for cell phones and other technologies. Given their knowledgeable position, with established connections to both industry and academia, ASTEM was able to provide valuable insight into what the current state of industry is and where it may head in the future. It was discussed that, although the skills gap is thought to be similar to that in the UK, the significant ageing and shrinking population may serve to catalyse this issue and result in work force shortages going forward - https://www.astem.or.jp/en/

Daikin – Daikin is a Japanese multinational air conditioning and refrigeration unit manufacturing company headquartered in Osaka. Daikin is the inventor of variable refrigerant volume systems (or VRV by Daikin air conditioning, other manufacturers remarked on this as VRF) and an innovator in the split system air conditioning market. It has over 60000 employees across global operations. The project visited the Shiga plant, which produces residential air conditioning units. https://www.daikin.com/index.html

Fanuc - Fanuc is the global leading manufacturer of factory automation systems with a worldwide annual revenue of $6.08 billion. Fanuc takes 65% of the global CNC market share and 29% of the global robotics market share. Fanuc's 3 main business divisions are:

FA (factory automation)- consisting of CNC, servo motor, servo amplifier and laser production.

ROBOT - consisting of articulated robots (including collaborative robots) and delta robots, incorporating intelligent features such as vision recognition systems, force sensors and 3D area sensors.

ROBOMACHINE - consisting of compact machining centres, electric injection moulding machines, wire-cut electric discharge machines and ultra precision machines.

The research project visited the global headquarters located at the base of Mt Fuji and tour the showroom, machining factory and servo motor assembly factory - http://www.fanuc.eu/uk/en

Hilltop - Hilltop is a Japanese company with offices and manufacturing capabilities in Kyoto, Tokyo and California. The company specializes in prototypes, custom CNC machining, short run productions, and quick turnaround products. Rapid prototyping of precision machining is their specialty. One of their core beliefs is that no human should do mundane jobs which could be done by a robot, or otherwise automated. They emphasize that already 30 years ago they started their small factory by moving to CNC machining and since then have continually pushed for more automation. Compared to other Japanese companies, Hilltop is notably less traditional, and encourages an open-minded working atmosphere where fun is an integral part to the working life. As part of this, employees are allowed to work on their own projects, encouraged to challenge current working practices. These projects lie in the field of digitalisation with focus on IOT which is seen within the company as the main trend in Japan at the moment. Over the last decade the company has diversified its core competencies by moving from being a CNC service provider to being a design consultant, product developer and provider of full digitalisation solutions. One of the main areas of interest in the closer future is the development of an automated CAD to CAM conversion package that will have a major impact on distributed CNC machining techniques. - http://hilltop21.com/

Hitachi - Hitachi's Digital Solutions division was visited in Tokyo. They are experts in the Internet of Things and Artificial Intelligence. Their focus is on leveraging the Group's more than 100 years' experience to become the go-to integrators of Operations and Information Technology. They "create value by using disruptive digital technology" both for projects within the Hitachi Group and for external companies on a consulting basis. Co-creation is key to the division's approach to helping customers innovate; they use a set of tools including Hitachi's Internet of Things platform, Lumada, to identify opportunities and deliver optimised solutions. - http://www.hitachi.eu/en-gb

IBM - International Business Machines Corporation (IBM), incorporated on June 16, 1911, is a world-renowned technology company. The Company operates through five segments: Cognitive Solutions, Global Business Services (GBS), Technology Services & Cloud Platforms, Systems, and Global Financing. The project concentrated on their Cognitive Solutions segment, which was visited in Tokyo. The Cognitive Solutions segment delivers a spectrum of capabilities, from descriptive, predictive and prescriptive analytics to cognitive systems. Cognitive Solutions includes Watson, a cognitive computing platform that has the ability to interact in natural language, process big data, and learn from interactions with people and computers. These solutions are provided through delivery methods, including through cloud environments and as-a-Service models. Cognitive Solutions consists of Solutions Software and Transaction Processing Software - https://www.ibm.com/ibm/us/en/

KIT - The Kyoto Institute of Technology (KIT) is a Japanese national university established in 1949. The Institute's history extends back to two separate schools, focusing on craft and sericulture. They were the forerunners of the Faculty of Engineering and Design and the Faculty of Textile Science, respectively. In 1949 the two schools merged to establish the present School of Science and Technology. Due to its history the Institute is one of Japan's main historical centers of textile research. A such, the visit to KIT focussed on Dento Mirai a concept that combines traditional craftsmanship with modern technology. Dento in Japanese means tradition and Mirai the future. The research division visited by the project focusses on understanding how traditional japanese products are manufactured by experts and how this knowledge could be applied in other fields with focus on automation. Special attention is given to japanese braiding techniques and ways on how these techniques can be used for carbon fibre to increase crashworthiness in automotive applications. https://www.kit.ac.jp/en/

Kyocera - Kyocera was founded in 1959 with 28 people as a specialist in fine ceramics when they developed the U-shaped kelcima, used in television electron guns. Kyocera are now a global corporation with 231 companies and over 70,000 employees. Kyocera is split into two main categories of business: components, and equipment & systems, with a roughly 50/50 split in size between the two. Within the components business, there is the industrial and automotive sector, semiconductor sector, and electronic devices sector. In the equipment & systems business there is a communications sector, document & solutions sector, and life & environment sector. Additionally, Kyocera also have a sector in the hotels business. Their wide ranging experience gives them a broad expertise and allows them to integrate the full range of processes from development and production to sales and logistics. During the overseas research project, the headquarters was visited. http://www.kyocera.co.uk/

METI – The research project had a meeting with representatives of the Ministry of Economy, Trade and Industry. METI was established in 1949 following the reorganisation of the Ministry of Commerce and Industry. METI is divided into six main trade bureaus, including the Industrial Science and Technology Policy and Environment Bureau, the Manufacturing Industries Bureau and the Trade Policy Bureau, as well as three Agencies and the Secretariat. Their primary role is to research and publish white papers and reports on Trade and Industry, but they also run and support a number of projects to help advance Japan's Manufacturing Industry. Their mission is to support the economic growth of private companies, develop external economic relationships, and secure stable and efficient supply of energy and mineral resources.

In 2017 there are a number of areas METI intend to focus on. These include the Fourth Industrial Revolution incorporating IoT, robotics and AI, developing a roadmap to investigate the mobility of people and goods, strengthening the critical infrastructure and human resource development for cyber-security, and reforming the traditional Japanese style employment system for an ageing society. In order to tackle these issues METI will publish papers and run programs and funding opportunities to encourage development. For example, METI fund some of the projects at ATR, and so drive the direction of some of the research. They are involved in projects such as promoting the use of open data by developing interfaces for private companies to use, or the SAMURAI project (Strategic Advancement of Multi-Purpose Ultra-Human Robot and Artificial Intelligence Technologies), one of the projects they collaborate on with ATR in which they research and develop AI capabilities. Other projects include those to encourage closer links between venture firms and big businesses, and options to exempt companies from certain regulatory restrictions to encourage innovation. http://www.meti.go.jp/english/

Murata - Murata is a Japanese manufacturer of electronic components, based in Nagaokakyo, Kyoto. Honorary Chairman Akira Murata started Murata Manufacturing as a personal venture in October, 1944. Murata Manufacturing is primarily involved in the manufacturing of ceramic passive electronic components, primarily capacitors, and it has an overwhelming presence worldwide in ceramic filters, high-frequency parts, and sensors. As of March 31, 2013 Murata Manufacturing has 24 subsidiaries in Japan and 52 overseas. The project visited the open innovation centre just outside of Kyoto. https://www.murata.com/en-eu

OMRON - OMRON corporation is an electronics company based in Kyoto, Japan. It was founded in 1933, and was incorporated in 1948. The main focus of OMRON is the manufacture and sale of electronic components and Intergrated Circuits. It also manufactures electronic systems and medical equipment, however the factory which was seen during the research trip did not specialise in these areas.

Notably, Omron developed the world's first electronic ticket gate for trains, and manufactured some of the earliest ATMs. During the Overseas Research Project, the manufacturing facility in Kusatsu was visited. The facility itself performed the production of PLCs, which remain one of Omron's flagship products. https://omron.co.uk/en/home

Preferred Networks - Preferred networks, founded in 2014, develop software that applies real time machine learning and deep learning for new applications in the IoT. Preferred Networks research, develop and sell computer hardware and software. Additionally, they consult in in the areas of data analytics, edge computing systems, distributed intelligence and machine learning, amongst other areas, providing custom solutions to client problems. Preferred networks collaborate with some of the other companies researched, mainly FANUC, whose robots they use on a regular basis. Preferred networks focus on research and open collaboration to help advance the quality of digital offerings and provide custom digital solutions to customers. - https://www.preferred-networks.jp/en/

Tsukino Katsura - Tsukino Katsura Sake brewery was founded in 1675 and its tradition has been passed down for 340 years by 14 generations of the Masuda family. In 1964 they created a new genre in sake known as Nigori-sake, a roughly filtered and milky sake, and became a nationally known sake brewery. Since it is bottled during the fermenting stage, Nigori-sake is effervescent and is known as the "sake sparkling". Tsukino Katsura also preserves probably the oldest aged sake in Japan, Koshu, dating back 50 years. Always striving to be innovative, Tsukino Katsura also grows special rice for sake called Iwai with the rice farmers in Kyoto and became the first sake brewery to make Junmai Daiginjo Nigori-sake which has become popular abroad as a sake that goes well with international cuisine. http://www.tsukinokatsura.com/

VPEC - VPEC, founded in 2012, has several patents on the proven technologies supporting their ECONETWORK vision. ECONETWORK stands for Electronic Cluster Operation Network, and is the underlying concept behind the super grid vision. The super grid vision is would allow energy resilience and security across Japan. The super grid will connect expensive Japanese grids to Asian, and ultimately global, energy networks, while aiming to produce up to 100% renewable energy.

Due to the lack of inertia provided by renewable energy sources, VPEC have designed a BESS system which simulates this inertia via battery and PV solar cell systems. Their patents centre around this core technology, and while regulation has held them back in Japan, they are currently aiming to deploy their proven system in Australia. This company currently has no manufacturing capability, but has a promising future. - http://www.vpec.co.jp/index_e.html

Appendix B. List of authors

This report was contributed to by the following 23 individuals :

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End