Industry 4.0

An Analysis of the Impact upon UK-based Automotive Manufacturing Organisations

‘A thesis submitted in partial fulfilment of the requirements of Nottingham Trent University for the degree of Doctor of Business Administration’

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May 2023

Abstract

Industry 4.0 is an emerging technology-based phenomenon that some have described as a new era in manufacturing, which is so potentially disruptive it has sometimes been labelled the fourth industrial revolution. It is argued that since the launch of Industry 4.0 in 2011 (Kagermann et al., 2013) there has been a distinct level of media hype, uncertainty and scepticism surrounding this high technology strategy. Given these uncertainties, this thesis aims to explore the level of Knowledge, Adoption and Impact within the UK automotive and manufacturing industry. Being that Industry 4.0 is still arguably emerging, it was decided that questionnaire surveys and interviews were the most appropriate instruments to provide the flexibility to answer the research questions.

It was found from both the interviews and the survey that the overall level of diffusion of Industry 4.0 within the UK automotive manufacturing sector is only beginning to emerge slowly. Despite over 10 years in the making since its launch in Germany in 2011 (Kagermann et al., 2013), the level of awareness remains surprisingly low within the UK automotive manufacturing industry. It was revealed that some within the automotive and manufacturing industry still fail to distinguish between Industry 4.0 and today's evolving industrial technologies, suggesting a level of confusion persisting within the sector.

In contrast, a small number of pioneers were found to have a more thorough understanding of Industry 4.0 and having taken positive steps to engage with this industrial phenomenon, looked to have pushed the boundaries further. With Industry 4.0 beginning to emerge in the UK, confusion has arisen within the automotive manufacturing sector entailing that the level of impact was somewhat difficult to determine.

It was observed from the interviews that the push for Industry 4.0 has attracted the attention of many technology providers in their attempt to sell technology and services. The research concluded that despite the 'revolutionary' jargon used as marketing hype by these organisations, for the moment Industry 4.0 within the UK automotive manufacturing sector is more around evolution than revolution.

Acknowledgements

I first would like to thank my family for their patience when I spent time away from them to work on this thesis. My wife Joanne, my daughters Alex, Ellie and Sophia and my son Joe - I thank them all for their patience.

I acknowledge both David Smith and Aquila Yeong from Nottingham Trent Business school. Without their support, guidance and mentoring this thesis would not be written, so I thank you for your ongoing support.

I would also like to thank Carol Tansley who first believed in me when others did not when, way back, I first started this doctoral journey. Carol's inspiration gave me the belief that this challenge was achievable.

Baback Yazdani for first giving me the opportunity to join the DBA group.

Finally, a thank you to my small team at Alchemist Consultants, particularly Vivian Calvert who has sometimes felt the brunt of my varying emotions during the ebb and flow of this research.

Contents

Tables and Diagrams

Practitioner Conferences

Bainbridge M., Impact of Industry 4.0 on UK Automotive, Advanced Manufacturing Forum, June 2022, Centre of Manufacturing Excellence, University of Sunderland, Sunderland UK.

Bainbridge M., Impact of Industry 4.0 on UK Automotive, Lean Workshop Group, April 2022, Centre of Manufacturing Excellence, University of Sunderland, Sunderland UK.

Chapter 1 - Introduction

Today's advancements in our technological society have seen a rapid development in what might be termed 'disruptive innovations'. Having become household names, organisations such as Airbnb, Alibaba and Uber have developed and diffused innovative product and services quicker than previously observed in the marketplace (Schwab, 2017). Advancements in industrial innovations have been just as rapid, and it is these more recent developments in digital industrial technologies which are arguably leading us into a new era. This new era can be labelled Industry 4.0 or Smart Manufacturing as an emerging concept which builds upon the flexible and intelligent manufacturing systems of the 1980's and 1990's with sensors, communication technology, computing platforms, data intensive modelling, predictive engineering and simulation (Kusiak, 2018).

The concept of cyber physical systems involves a number of tools - the internet of things, service-based computing, cloud computing, artificial intelligence and data science - constituting an evolution in the way products are manufactured and services delivered (Kusiak, 2018). These new relationships between complementary technologies can arguably change the way in which products are manufactured. They do so not least through improved utilisation of resources where the ability to adapt quickly and effectively to meet the needs of management and customer demands provides more efficient ways of manufacturing products effectively and improving industrial services (Kamble et al., 2018).

As a concept, Industry 4.0 can be understood as an emerging technological movement with its foundations in the 2011 high technology manufacturing strategy put in place by the then government of Germany. Here, the final government report published by the Industry 4.0 Working Party stated that "Industry 4.0 will involve the technical integration of Cyber Physical Systems CPS into manufacturing and logistics and the use of the Internet of Things and Services in industrial processes. This has implications for value creation, business models, downstream services and work organisation" (Kagermann et al., 2013). As a consequence, some authors emphasise that the technological connections between old and emerging technologies have become so disruptive that it is accurate to use the expression

‘The Fourth Industrial Revolution’ (Kamble et al., 2020; Liao et al., 2017; Pereira & Romero, 2017).

1.1.0 Research Context

Since 2004, the researcher has held a position within the industry as a learning and development consultant particularly focused on the lean and operational excellence agenda. The sectors of particular focus to the researcher are manufacturing, automotive manufacturing, engineering and logistics. The various roles that the researcher has undertaken over these 17 years have ranged from being a practitioner and then a senior practitioner, to running a consultancy firm as managing practitioner and having 25 lean engineers operating within this function. After having worked in two placements within the industry as a site lead for a Dutch FMGS business and the General Manager of a German third-party automotive logistics firm supplying Europe’s most productive automotive plant, the researcher now owns and runs a training and consultancy business operating within the afore-mentioned sectors. Throughout this time, the researcher has built up a significant network for people who still operate within the manufacturing, automotive, engineering and logistics sectors.

The original idea for the thesis came from a 24-month project which was delivered within a UK-based maritime organisation, principally engaged in shipbuilding and repair. This work-based project was a leadership development programme led over an engagement period of 24 months. After over 40 interviews and observations, one of the many concerns identified by the project diagnostic was the failure of the senior leadership within the organisation to engage with the abundance of knowledge and creativity demonstrated by the interviewees.

The original focus for this DBA was to explore Kurt Lewin’s (1946) action research cycle and ascertain how the two competing phenomena of lean and innovation might be used as an enabler to solve organisational problems. The specific question posed was how lean can be used an enabler of innovation through the engagement of staff within a UK-based shipbuilding business. Although the organisations agreed to participate in the research, internal political developments (not caused by the research) within the company has caused significant turbulence and unrest, manifested in strikes, leadership changes and increased levels of workforce hostility. Due to these increased levels of volatility within the host organisation, the original research subject had to be refocused.

After time away from the research for personal reasons, the researcher began to hear terms like ‘industrial revolution’, ‘Industry 4.0’, ‘smart manufacturing’ and ‘digital manufacturing’ appearing with increasing frequency within the network. As time progressed, the concept of Industry 4.0 has become more present within the agenda of industrial practitioners and industry alike. The automotive trade shows attended by the researcher over the last 3-4 years were a testament to the efforts of many consultants and technology providers to refocus their marketing emphasis on this phenomenon. But understanding what Industry 4.0 is from the outset is confusing as the ideas are similar to concepts, such as smart manufacturing, agile, integrated manufacturing and digital transformation. Judging by initial discussions with colleagues within the industry, the range in understanding of the phenomenon is significant with many believing Industry 4.0 represents the development of increased levels of industrial automation. Other discussions with industry colleagues have led them to explain that Industry 4.0 is a new approach to maintenance-based manufacturing.

In the quest to understand more about this industrial movement, the initial engagement with the literature revealed that many consultants and technology providers discuss this phenomenon in hyperbolic, revolutionary terms. Trying not to be caught up with this ‘band-wagon’ of hype, it has proven difficult to establish whether or not Industry 4.0 was just another movement which transitioned in and out of industrial ‘fashion’. Movements such as Total Quality Management (TQM), Production Led Maintenance (PLM), Total Preventative Maintenance (TPM) and perhaps even Lean have all come about to reflect the latest industrial trend towards improving operational performance, with many more approaches to come. Preliminary research preparing the proposal for this thesis has established that there is an abundance of consultancy literature disseminating ideas about the 4th industrial revolution, but this thesis does not set out to uncover whether or not this is the next revolution.

In fact, an agreed definition of Industry 4.0 was difficult to establish even at the proposal stage, while the discovery that the idea of Industry 4.0 was developed by German government, industry and research institutes (Kagermann et al., 2013) added more interest. The interest of specific German institutes was due to what was arguably the dominance of Germany's engineering and automotive manufacturing industry. The researcher then discovered that similar initiatives have been launched by governments around the world, including the UK, which has added further interest to establishing what this industrial movement is about. If this phenomenon is an industrial fad like those mentioned previously, then why are governments around the world rethinking industrial strategy and making efforts to work towards a digital future?

1.1.1 Research Focus

Given all the uncertainties outlined above regarding this industrial movement, the aim of this thesis is to explore how UK automotive manufacturing are engaging with the principles of Industry 4.0 and, if so, how are they realising these principles?

1.1.2 Research Questions & Structure

To add clarity to this industrial phenomenon called Industry 4.0 the research questions are as follows:

- ***RQ 1***. What is understood by the term Industry 4.0 within the UK automotive manufacturing Industry?
- ***RQ 2***. To what extent are UK automotive manufacturing firms adopting Industry 4.0?
- ***RQ 3.*** What is the impact of these technologies on business and workers?

Regarding the fundamentals behind this phenomenon, the results of the first question will determine the level of knowledge and understanding possessed by the people within the organisations researched. For without knowledge and understanding of Industry 4.0, implementation efforts will likely be hampered.

Understanding how these companies are engaging with the technologies and determining the level of engagement demonstrated within each company will hence be key to determining how best to respond to the second question within the research. The factors to be considered here are the following: the technologies being used; why, how and where in the organisation are the technologies introduced; and what does the company want to achieve through the introduction of these technologies into their business.

The final question will seek to understand the impact and level of success these technologies have achieved on the host business and their workers. Here, fulfilling research objectives will not merely be a case of determining the impact, but to determine whether or not the technologies are well-placed to transform the companies in readiness for the digital future.

Therefore, this thesis has set out to explore what UK automotive manufacturing businesses understand to be Industry 4.0 and how they are adopting the principles and technologies of the Industry 4.0. It has then focused to understand the level of impact of Industry 4.0. Each chapter has undertaken an empirical analysis while exploring questions of design and process with corresponding ethical issues raised for industry.

Chapter 1 has set out why this digital phenomenon is arguably of significance in today's manufacturing and automotive sectors, providing a rationale as to why the Industry 4.0 phenomenon is worthy of this DBA thesis. A presentation of the research questions to be answered has been discussed with an explanation and justification of these questions in the light of the overall objectives of the research.

Chapter 2 discusses and assesses the Industry 4.0 literature most pertinent to the study with the aim of establishing possible research gaps. Here, initial research will provide evidence of where the movement started and why, while explaining why the question of whether or not Industry 4.0 is the Fourth Industrial Revolution will be excluded from this study. A survey of the various visions of Industry 4.0 will then be presented, including a discussion regarding the concept of the smart factory. The next step in the literature review will be to understand the phenomenon in more detail by trying to establish an agreed definition. The technologies involved will then be discussed along with a justification as to why these technologies have been chosen for study. The final part of the main body of the literature review will look at the impact of Industry 4.0 as presented within the literature selected in the papers most pertinent to the research objectives.

Chapter 3 introduces the conceptual framework which is built upon the research of Frank et al., (2019) and the transformation process model used in operations management literature such as Slack et al., (2019). The research questions of knowledge, adoption and impact are overlayered with the input, process and output aspect of the transformation model. Using these concepts has allowed the researcher to provide clarity around the research questions which chapter 3 then outlines. Having begun with a general overview of the model, we then discuss each of the three pillars and how a particular conceptual framework has been used to operationalise the research.

Chapter 4 presents the methodological choices taken to achieve the objectives of this research. The development of a “research onion” by Saunders et al., (2016) is used here as a structure to plot the methodological path selected and justify it. The starting point will be to justify the philosophy which is more suitable for exploring and refining the research questions. The research approach will then be discussed, outlining its key benefits in a subsequent presentation of a dual approach of surveys and interviews, initially beginning with a justification of the research tools selected then followed by a discussion and analysis of the method behind each of the research strategies. The final section of the methodology will summarise the challenges faced right from the beginning of the empirical analysis undertaken.

The main research findings are presented and discussed in chapter 5. As an empirical investigation, a concrete approach to answering the research questions will provide a more structured approach to evaluating the findings and drawing conclusions based upon the methods used. The first section provides general thoughts on Industry 4.0 taken from the interviews. The following three sections on the knowledge, adoption and impact of Industry 4.0 are structured according to the survey and then the interviews conducted. Corresponding conclusions will be drawn for each research question and according to the research method overall. Finally, all the conclusions will be drawn together and summarised in order to provide full responses to the research questions. Research limitation and ideas on further research will also be presented.

Chapter 2 - Literature Review

2.1 Introduction

The emerging nature of Industry 4.0 has produced a quite complex, multi-faceted body of literature. Table 1.0 illustrated below provides a mere snapshot of the themes and growing body of literature surrounding the Industry 4.0 phenomenon. From the outset, the literature is complex and technical with numerous themes that might prove somewhat confusing. The following review will hence place a first emphasis on a general understanding of the literature, then focus upon the central themes of the research which are outlined below.

The opening chapter of this study began by discussing the origins of Industry 4.0, explaining why this industrial movement was embraced by the German government, research institutes and industry. In response, this chapter will explore what other industrial nations are doing to assist in their individual push towards Industry 4.0/smart manufacturing. Here attempts have been made to pin down an agreed definition of Industry 4.0. In doing so, each definition will be broken down and discussed in detail.

Table 1.0: The Landscape of the Research Literature

Industry 4.0 Literature Landscape	Authors
Lean and Industry 4.0	(Buer et al., 2018 ; Sanders et al., 2016a; Wagner et al., 2017)
The future of work and employment	(Bonekamp & Sure, 2015; Frey & Osborne, 2013)
The future of skills and ideas around the notion of education 4.0	(Hussin, 2018; Salmon, 2019; Wallner & Wagner, 2016)
Industry 4.0 and the circular economy	(Geissdoerfer et al., 2017 ; McDowall et al., 2017).
Industry 4.0 and supply chain	(Ivanov et al., 2019; Tjahjono et al., 2017)

Healthcare	(Cavallone & Palumbo, 2020)
Industry 4.0 and analytics	(Gröger, 2018; Santos et al., 2017)
Cloud and cloud manufacturing	(Ellwein et al., 2019; Wu et al., 2013)
Big data	(Cui et al., 2020; Xu & Duan, 2019)
Internet of things	(Gilchrist, 2016; Leloglu, 2016)
Cyber physical systems	(Napoleone et al., 2020; Romero-Silva & Hernández-López, 2020)

The approach presented above aims to search for key words and terms (Tranfield et al., 2003) associated with this industrial movement. From the outset of the literature review, the terms ‘smart’, ‘digital’, ‘advanced manufacturing’ and ‘Industry 4.0’ all seemed to be used interchangeably. These ideas will be explored further within the literature review. For the moment, it should be said that the emerging nature of Industry 4.0 provides a challenge in determining and selecting the right technologies to analyse within the literature.

In trying to make sense of the complex nature of the technologies, this literature review will provide a general overview of what Franks et al., (2019) describe as the base technologies of Cloud, Big Data and Analytics, and the Industrial Internet. Added to this technological grouping will be cyber physical system, as Kagermann et al., (2013) suggest that this technology is a key enabler of Industry 4.0. The impact of these technologies will then be discussed with a particular focus upon their adoption and impact in the context of their future employment.

2.1.1 The Origins and Visions of Industry 4.0

The term ‘Industry 4.0’ was first used in 2011 by Germany’s Federal Ministry of Education and Research, which is an industrial working group made up of government officials, research centres, business leaders and academics. The term was used to describe a strategic initiative for an industrial movement designed to strengthen national competitiveness with a particular focus on German product and equipment manufacturing, then recommending a dual approach to an intensively technology-based strategy (Henning, 2013).

This emphasis built up the competitivity of the German manufacturing industry and manufacturing equipment sector through the optimisation of existing IT-based processes. The strategy was hence to unlock a global network and integrate cyber physical systems (CPS) into manufacturing and logistics, using the Internet of things and new services in industrial processes. This leveraging of existing technologies combined with the know-how of Germany's workforce and systemic innovation was to create an optimal competitive advantage for German industry (Kagermann et al., 2013).

The original vision outlined by the German industrial working group was to establish an overall programme able to integrate with existing technologies and economic potential through a systematic process of innovation leveraging the skills, performance and know-how of Germany's workforce (Kagermann et al., 2013, p. 22). Elsewhere, Lichtblau (2015, p. 12) identifies a study conducted in Germany predicting that through business process efficiency gains, new business models, innovative products and network optimisation industry would enjoy an annual growth of 21% up until 2025 bringing an additional 23 million euros to the sector.

Further predictions suggested that integrated manufacturing elements would control themselves independently and exchange information autonomously (Pereira & Romero, 2017). These manufacturing processes included production engineering, production planning, product design and the manufacturing of products linked end-to-end and controlled independently (Ebrahimi et al., 2019).

The energy behind this industrial movement came from the increased competition coming principally from the US and Asia. The Industry 4.0 working party instituted in Germany thus outlined that by improving resources efficiency, meeting increasing flexibility with customer requirements, and optimising value by creating new services, optimising decision-making and improving operational flexibility, then the movement would become the competitive differentiator enabling the high-wage economy of Germany to compete in a global marketplace (Kagermann et al., 2013; Alcácer & Cruz-Machado, 2019).

According to Kagermann et al., (2013), the term Industry 4.0 relates to the 4th stage of the industrial revolution. Thus, Industry 4.0 is a label which these authors used to explore its implications for industry which, in their opinion, had the potential to be as impactful to industry and society as what was witnessed during the first industrial revolution. This first industrial revolution occurred in Britain in 1784 and was categorised by a shift in technology, causing a widespread shift towards industrialisation and leading to new ways of working for many people within industrial nations (Agarwal & Agarwal, 2017).

However, the notion of a 4^{th} industrial revolution is nothing new. Authors such as Liao et al., (2017) present evidence that the term '4th Industrial Revolution' was first suggested by Rostow (1988) regarding the process of invention to innovation. Parthasarathi and Thilagavathi (2011) and Hung et al., (2012) also present this term with regard to advancements in nanotechnology. However, Culot, Orzes et al., (2020) report that evolving technological uncertainties make it challenging to compare today's innovation with the properties of previous industrial revolutions. The authors suggest that the technologies have mostly been analysed and hypothesised individually but the aggregated effect has not yet been confirmed.

Advancement in industrial technology applications have not only been within Germany in recent time as the US launched the advanced manufacturing partnership (AMP) in 2011, the French government 'La Nouvelle France Industrielle' in 2013, in China they refer to 'Made in China 2025', while the Dutch have 'smart industries' and in Belgium manufacturing is 'made different – the factories of the future' (Liao et al., 2017; Nosalska et al., 2019). The Japanese have taken this one step further, with their 5th science and technology basic plan corresponding to their vision of the 'smart society' (Oztemel & Gursev, 2020a).

In 2013, the UK Government launched its own project with some 300 academics, industry experts and business leaders coming together to create the 'Vision for UK Manufacturing' initiative. This government initiative ran over a period of two years through the UK government's Office for Science under the personal direction of their chief scientific advisors. The team set out a strategic overview of

UK manufacturing as far ahead as 2050. This document established four characteristics and their implications of the future of manufacturing for the UK government: *faster more responsive and closer to customer; exposed to new market opportunities; more sustainable; and increased dependency upon highly skilled workers* (Government Office for Science, 2013).
These ideas will be further discussed in the subsequent literature review.

2.1.2 Defining Industry 4.0

Despite the increasing number of publications surrounding the Industry 4.0 phenomenon, there is some debate in the literature over a clear definition of Industry 4.0 (Alcácer & Cruz-Machado, 2019; Culot, Nassimbeni, Orzes, & Sartor, 2020; Ghobakhloo, 2018; Glas & Kleemann, 2016; Mrugalska & Wyrwicka, 2017). The paper presented by Kagermann et al., (2013) after the 2011 Hanover fair is arguably the first mainstream publication to address Industry 4.0 and will therefore be the starting point for determining an agreed definition of Industry 4.0. The afore-mentioned paper is arguably not an academic publication, but a document developed by academics from across government, industry and research institutes as a guide to assist German industry in securing its future for manufacturing. Not only does this background give the report credibility, but it provides additional justification as to why it has been used as a starting point for defining this industrial movement.

Table 2.1: Defining Industry 4.0

Definition	Authors
"*The fourth stage of the industrial revolution is based on cyber physical systems. Industry 4.0 will involve the technical integration of CPS into manufacturing and logistics and the use*	(Kagermann et al., 2013)
of the Internet of Things and Services in industrial processes. This will have implications for value creation, business models, downstream services, and work organisation."	

"…the fourth industrial revolution, a new level of organizing and controlling the entire value chain across product lifecycles. This cycle focuses on increasingly personalized customer wishes and extends from the concept to the order, development, production, and shipping of a product to the end customer and ultimately to its recycling, including all associated services."	(Lichtblau et al., 2015.)
Oztemel and Gursev (2020) suggest that *"Industry 4.0 is a manufacturing philosophy that includes modern automation systems with a level of autonomy, flexible and effective data exchanges encouraging the implementation of next generation production technologies, innovation in design, and more personal and more agile in production as well as customized products."*	(Oztemel & Gursev, 2020, p. 40)
"The concept of organizational and technological changes along with value chain integration and new business model development that are driven by customer needs and mass customization requirements, and enabled by innovative technologies, connectivity and IT integration."	(Nosalska et al., 2019)
"*Industry 4.0 in its simplest form concerns enabling manufacturing with the elements of tactical intelligence using techniques and technologies such as big data, the internet of things and cloud computing."*	(Trappey et al., 2017)

Table 2.1 above provides a snapshot of five definitions of Industry 4.0 beginning with Kagermann et al., (2013) who present a compelling conceptual vision for Industry 4.0 proposing several key benefits to the implementation of the technologies. The authors define Industry 4.0 as the "*fourth stage of the industrial revolution based on cyber physical systems. Industry 4.0 will involve the technical integration of CPS into manufacturing and logistics and the use of the Internet of Things and Services in industrial processes. This will have implications for value creation, business models, downstream services, and work organisation."* However, the conception of Industry 4.0 presented by Kagermann et al., (2013) suggesting that it is an industrial revolution is arguably unfounded at this point.

What the authors are actually doing here is merely making a prediction of the potential impact that the technologies may have upon industry. These estimates of potential impact are evident within the latter part of the authors' definition. Although the statement from the authors suggests two evolving technologies - the cyber physical systems and the internet of things - it provides little in the way of clarification. Without a detailed understanding of the internet of things and the cyber physical system, this statement is arguably too vague to contribute to any further understanding of this phenomenon.

Further efforts by the German government to advance the movement led to a 2014 research project sponsored by VDMA IMPULS-Stiftung and other prominent German research institutes, who then published a paper on Industry 4.0 readiness (Lichtblau et al., 2015). This steering committee define Industry 4.0 as *"the fourth industrial revolution, a new level of organizing and controlling the entire value chain across product lifecycles. This cycle focuses on increasingly personalized customer wishes and extends from the concept to the order, development, production, and shipping of a product to the end customer and ultimately to its recycling, including all associated services*" (Lichtblau et al., 2015).

The definition presented by Lichtblau et al., (2015) does provide further detail about this predictive description of the 'what if' possibilities relating to Industry 4.0. In fact, this relatively early definition of Industry 4.0 suggests that the technologies would no longer be focused purely upon shop-floor operations but span the entire value stream of the business for a more integrated and controlled approach to efficiency and utilisation. This conception arguably suggests a more holistic transformation and lifecycle process where each part across the whole value chain is interconnected to form an aggregated vision of the existence of a product. With this connectivity, the authors predict both advances and new approaches within business models, sustainability and customer requirements throughout the life cycle of products. If, as the authors suggest, the product is interconnected throughout its life cycle and through to recycling, then changes to the old methods of doing business might perhaps change. Arguably then, the potential effect would be for existing business models to change which would back up the predictions of the authors. However, if predictions alone are being offered by the authors, then analysis will remain in the abstract here entailing that further discussion is required of Industry 4.0.

Throughout much of this debate to this point, to claim so early in its emergence that Industry 4.0 is the start of an industrial revolution has arguably been a point of weakness. While this thesis will not argue this to be the case, it should be said that to make this claim based upon the conceptual ideas of the integration of existing technologies does require significantly more research to justify it. As outlined previously in the origins section of this thesis, similar initiatives have been identified to be evolving within industrial nations around the world, with corresponding terms used such as ‘smart factories’, ‘factories of the future’, ‘advanced manufacturing partnership’ and ‘a future vision for manufacturing’. What can be drawn from the evidence is that advancements in industrial technologies are causing nations to rethink industrial strategy, although to call this the fourth industrial revolution is still open to much debate (Liao et al., 2017; Nosalska et al., 2019; Oztemel and Gursev, 2020a). Arguably, what Lichtblau et al., (2015) are offering is just another prediction of the potential of Industry 4.0.

In fact, Oztemel and Gursev (2020) provide a very detailed literature review on Industry 4.0, focusing on the conceptual impact of the technologies on industry and society. As they note, early discussions sought a road map for the execution of Industry 4.0 but the evolving nature of the phenomenon has made this difficult to accomplish. Although bringing together the extensive literature in one place is one specific aim of that paper, its actual contribution to academic thinking may be limited because the article summarises what other researchers have already stated and provides limited additional information nor any solutions for business and industry. However, the authors do suggest a ‘concrete definition’ of Industry 4.0 which they argue is needed both academically and practically, even if defining a phenomenon still evolving perhaps limits the opportunities additional for emerging innovations.

Oztemel and Gursev (2020) suggest that “*Industry 4.0 is a manufacturing philosophy that includes modern automation systems with a level of autonomy, flexible and effective data exchanges encoring the implementation of next generation production technologies, innovation in design, and more personal and* *more agile in production as well as customized products"* (Oztemel & Gursev, 2020, p. 40). This definition presented by Oztemel & Gursev (2020) places the emphasis on terms such as modern automation, effective data exchanges, innovation in design, agility in production and customising products, all of which are technologies and applications now in use in many of today's manufacturing plants.

However, where this definition suggests *"next generation production technologies"*, it provides no further explanation into what these are. Given that few additional ideas have been offered to the industrial technologies already in place, for the authors to state that their definition is a 'concrete definition' of Industry 4.0 may well be a weakness in view of the ongoing attempts to define Industry 4.0 as a phenomenon that is still evolving. Moreover, in the same article the authors also suggest that the impact of Industry 4.0 will be the transformation of society, economy, trade and education but state in their own definition that Industry 4.0 is a manufacturing philosophy. Indeed, there is a growing body of literature around Industry 4.0 suggesting that the movement can be used within many disciplines, from agriculture (Zhai, et al., 2020) to healthcare (Aceto, Persico, & Pescapé, 2020), not to mention logistics (Winkelhaus, & Grosse, 2020).

Nosalska et al., (2019) also claim to have introduced a coherent definition of Industry 4.0 through a review of 52 literature publications through 2011-2017. The approach of their analysis was to synthesise the various meanings of the term 'Industry 4.0' by reviewing key descriptive elements which they claim enable a coherent, versatile and consistent formulation of an up-to-date definition with academic rigour. This article was structured in such a way as to separate the consultancy publication from that of the scientific articles, which is a key strength when determining an agreed academic definition separate from the consultancy jargon. Their own literature review underlines how existing academic papers mainly focus upon the technological enablers of Industry 4.0, identifying those cyber physical systems and the internet of things which they take to be the key ingredients in the implementation of intelligent production systems (Nosalska et al., 2019, p. 8). They conclude that the Industry 4.0 concept is driven by advancements in technology such as augmented reality, additive manufacturing, AI, cloud computing and big data.

Nosalska et al., (2019) also recognise that due to the complexity of Industry 4.0, finding a clear, universally accepted definition will be a difficult ask. They do present more-or-less eleven different definitions of Industry 4.0 within the text, while stating that having sifted through a total number of 697 papers reviewed, concluded that 52 of these papers have contributed to their definition of Industry 4.0. Nonetheless, they do offer a unitary definition of Industry 4.0 as a *"concept of organizational and technological changes along with value chain integration and new business model development that are driven by customer needs and mass customization requirements, and enabled by innovative technologies, connectivity and IT integration."*

The definition offered by Nosalska et al., (2019) hence introduces a slightly different dimension to those offered by the previous authors. In this definition, the authors introduce the idea of organisational change to introduce a different reality and a pragmatic dimension to the discussions of this phenomenon. Full integration and control of the value chain and product life cycle, integration of next generation production technologies would not appear to be implemented so easily. The size and complexities of value chain may even hinder or prevent the integration of the Industry 4.0 technologies. Arguably this integration of the technologies then creates a need for a change in skillset for the workers within the operation. Without a company-wide change programme, the possibilities of full-scale adoption of Industry 4.0 may thus become a barrier to success, as among other issues they could introduce an element of risk to the business. Although the author does acknowledge the definition is still conceptual, this notion of organisational change arguably introduces a realistic dimension to what the authors previously predicted to be a more revolutionary, utopian vison.

Details about the barriers to implementation will be discussed within the impact section of this literature review. For the moment, it is worth citing an additional strength of this definition in the concept of enabling. While the authors do not explain what the innovative technologies in question are, they do suggest connectivity and IT integration will be key enablers in the successful implementation of Industry 4.0. While Kagermann et al., (2013) suggested technology integration as key to the rolling-out of the fourth industry revolution, Nosalska et al., (2019) further develop this explanation to introduce IT integration and connectivity as key enablers.

Another impartial, uncomplicated and non-revolutionary definition of Industry 4.0 is presented by Trappey et al., (2017). The authors note that "*Industry 4.0 in its simplest form concerns enabling manufacturing with the elements of tactical intelligence using techniques and technologies such as big data, the internet of things and cloud computing".* Here the authors present and describes two key forms of intelligence: algorithmic and tactical. Algorithmic intelligence uses a process to achieve a goal, while tactical intelligence reaches a goal by considering changing factors (Trappey et al., 2017, p. 209). Tactical intelligence is presented by Trappey et al., (2017) as a response to changes within the environment utilising IOT, cloud computing and big data analytics. This concept can outline how to reach a destination by taking consideration of changing factors e.g., checking a car's tire pressure to compensate for changing road conditions.

Although clear similarities can be drawn with the computer-integrated manufacturing of the 1980's, this notion of real-time, data-driven decision-making is perhaps the key differentiator. Trappey et al., (2017) explain that tactical intelligence can now be integrated with collective technologies to allow decisions and changes to be made in real time within the manufacturing system. In this sense, the authors define tactical intelligence simply as what Industry 4.0 does. A counter-argument to this conception is that real-time decision-making is nothing new; for instance, the Toyoda automatic loom developed in 1924 was perhaps the first automated machinery to stop once abnormalities are found (Global Toyota, 2021). This stop-and-fix principle further evolved into what is now known as the Toyota principle of Jidoka which, loosely translated, means automation with a human touch (Romero et al., 2019). However, what is different is how the concept of tactical intelligence is applied to the digital technologies of Industry 4.0 such as big data, the internet of things and cloud computing.

Arguably then, to develop this tactical intelligence concept further within the context of Industry 4.0 is to use the metaphor presented earlier here with regard to the idea of a technology eco-system. Within a biological ecosystem, living organisms interact with each other within their environment and often interact with each other to survive. Similarly, the Industry 4.0 technologies operate and interact within their own environment, relying on each other to perform their tasks so the manufacturing system can operate in its most efficient way. It is within this industrial ecosystem that technologies interact, make decisions, provide feedback on performance and constantly push the boundaries of improved performance and effectiveness. Under this concept of an industrial ecosystem, today's industrial technologies are hence interconnected and aggregated through the digital technologies of Industry 4.0 which enables a manufacturing system to evolve. It is not then a single technology that realises Industry 4.0, but a calculated selection of technologies that interact with each other to make their eco system.

Culot et al., (2020, p. 2) present a comprehensive literature review analysing approximately 100 definitions of Industry 4.0. Though they present both academic and non-academic categorisations involving six coding categories to encompass elements of Industry 4.0, they offer no definition of it. Instead, 81 academic publications are used within the academic literature review. The coding categories used by the authors here are 'label', 'scope', 'enabling technologies', 'other enablers', 'distinctive characteristics' and 'expected outcome' (Culot et al., 2020, p. 4).

However, there are still so many uncertainties in the debate surrounding the Industry 4.0 movement, entailing that to present a definition would be reductive. Instead, as Culot et al., (2020) report, owing to the fact that the phenomenon is still in its infancy the original label presented by the Germans has been contaminated by other schools of thought. They suggest that Industry 4.0 was originally described as the fourth industrial revolution but it has now become a de-facto label for the phenomenon as much confusion still exists. This confusion is principally due to the constant evolving technology landscape, leaving many open questions as to its applications and maturity (Culot et al., 2020, p. 2).

Going on the evidence presented within this literature review, the early definitions provided by the likes of Kagermann et al., (2013) and Lichtblau (2015) present a series of ideas regarding the possibilities of this concept of Industry 4.0. But as academic research has grown surrounding the phenomenon and the early signs of empirical investigation have started to appear, researchers and industry alike are only beginning to see the possibilities of what this concept can achieve. In essence, the concept of Industry 4.0 is still emerging and with this emergence comes uncertainties. As Culot et al., (2020) have highlighted, there are still many unanswered questions around Industry 4.0, and to define something which is not fully understood could be reductive in view of the significant level of confusion that still exists.

Culot et al., (2020) initially began by trying to label the phenomenon, reporting that most of their findings about the labelling of Industry 4.0 resonate with the idea of a new paradigm in manufacturing driven by ICT innovation. They also present evidence suggesting that labels such as 'cyber' place attention on the exchange of data being processed via interconnected systems. 'Cloud manufacturing' is where manufacturing capabilities are controlled and serviced from within the cloud.

'Smart manufacturing' is where the usability of an object is enhanced with additional features connected to a manufacturing system, which is merely an extension to the common word for 'smart', similar to the label 'intelligent manufacturing'. Here the authors also suggest that digital transformation should be understood in terms of the concepts of strategic and business model innovation and the industrial internet often identified within the literature (Culot et al., 2020 p. 4). Culot et al., (2020) then present evidence from Boyes et al., (2018) suggesting that the 'industrial internet' is a term considered to be the US version of 'Industry 4.0'.

The initial work of Culot et al., (2020) on labelling do subsequently add clarity to how a sample of the literature currently label Industry 4.0 and so further the debate into how best to define this phenomenon. In line with the evidence presented by Nosalska et al., (2019), Culot et al., (2020) suggest that ICT innovations are leading to a new paradigm in manufacturing where the technologies are now interconnected and integrated at an aggregated level. In terms of providing further clarification of Industry 4.0, the authors then further explain labels such as 'cyber', meaning the interconnected data exchange, and 'clouding computing' meaning manufacturing capabilities controlled and services through the cloud. Such explanations provide an unbiased description of labels associated with Industry 4.0 and interconnected ICT innovations.

Culot et al., (2020) recognise that the scope for Industry 4.0 has shifted and is no longer unique to manufacturing, as suggested by Kagermann et al., (2013); Oztemel & Gursev, (2020); Trappey et al., (2017) all mentioned above. Out of the 81 academic publications used here, 22 encompass other economic sectors while 18 identify impact on consumer and society. The authors then discuss key enabling technologies in order to understand and define Industry 4.0 which will be covered within the technology section of this literature review. Interestingly, Culot et al., (2020, p. 2) then present further evidence that some of the authors within the literature review have chosen to understand Industry 4.0 based on what they term *'distinctive characteristics'* or referred to elsewhere as *'design principles' or 'functionalities'.* The author presents nine of these characteristics, the main four of which are process integration, real-time information transparency, virtual representation of the real world, and autonomy, joining key themes of real-time information, autonomy and process integration as common themes running all the way through the literature. The final part of Culot et al., (2020) work then presents a range of micro level and macro level possible outcomes or impact of Industry 4.0 which will be covered within the impact session of this literature review.

Perhaps a strength of the work presented here by Culot et al., (2020) is that it serves to break down the complexities of the phenomenon in a way which displaces a lot of the technical jargon. The authors bring together a complex multifaceted phenomenon such as Industry 4.0, using six coding categories to define their elements and enable a deeper understanding of the phenomenon from several different perspectives by providing a more triangulated view in understanding its complexities. Although they present evidence from the literature regarding each of the coding categories, they offer no definition of Industry 4.0 in an otherwise comprehensive literature review. They report that there has been a new shift in manufacturing brought about by ICT innovation and use additional labels such as Cyber, Cloud, Smart and intelligent manufacturing. The description presented by the authors describes in detail to how these technologies are used, allowing additional clarification into understanding Industry 4.0. The authors then further develop this 'usability' idea through the discussions of interconnectivity, aggregation, real-time information and autonomy of these new technologies. Perhaps a key strength of the authors is their recognition that Industry 4.0 is still new and an emerging technology, despite the need from academia and industry to explore it. Indeed, in view of the sheer quantity of literature reviewed as part of their research they suggest that it is too early to define the phenomenon (Culot et al., 2020, p. 12). The upshot of the attempts in this section to define Industry 4.0 is that the phenomenon is complex, lacking clarity and somewhat confused in terms of defining the differences between existing industrial technologies and that of the new movement.

While Culot et al., (2020) do begin to make sense of this ‘noise’, it is the work of Frank et al., (2019) that provides clarity when making sense of the complex integration of these technologies. In the name of improving the clarity around the complexities of Industry 4.0, the authors present a theoretical framework (Frank et al., 2019, p. 4) which suggests that the technologies associated with Industry 4.0 are split into two main functionalities. The ‘front end’ technologies of smart manufacturing, smart products, smart supply chain and smart working are concerned with operational and market needs. Then the base technologies of internet of things, cloud, big data and analytics provide the intelligence and connectivity to the front-end technologies (Frank et al., 2019, p. 5). The authors suggest that this enabling of connected intelligence is the main difference between Industry 4.0 different and previous industrial stages. The front-end technologies are then to be split into the two main dimensions of smart manufacturing/smart products and smart supply chain/smart working.

Frank et al., (2019) suggest that smart manufacturing is the central pillar of Industry 4.0 comprising of the technologies associated with the production system, also known as the operational technologies. Smart products are associated both with the market’s product offering and the external value added to the customer through feedback data and information given back to the production system. The technologies serving as integral parts of the smart manufacturing include operational flexibility, energy management, automation, traceability, vertical integration and visualisation (Frank et al., 2019, p. 5). Smart products are then the components which help to enable digital capabilities and services with products. These technologies for smart products include product connectivity, monitoring, control, optimisation and autonomy (Frank et al., 2019, p. 7).

Interestingly, Frank et al., (2019) suggest an evolutionary model for the enabling of Industry 4.0, beginning with smart manufacturing then moving onto smart products. Smart supply chain and smart working are the other complementary grouping of front-end technologies associated with the ensuing efficiencies achieved for operational activities. Smart working then concerns the use of technologies associated with improving the productivity and flexibility of the tasks performed. These technologies include augmented and virtual/augmented reality, collaborative robotics, remote monitoring of production and remote operation of production.

The smart supply chain subsequently focuses upon improving the supply of raw material and the delivery of finished goods and includes digital platforms with customers, suppliers and other company units (Frank et al., 2019, p. 8). Here the authors suggest that the idea behind the base technologies of the internet of things, cloud computing, big data and analytics is to provide the manufacturing system with intelligence through aggregated interconnectivity (see figure 2.0 below), adopted from Frank et al., (2019). Each of these associated base technologies will be covered in the technologies section of this thesis. The interesting aspect about this work is that the emphasis on integration goes beyond manufacturing and into the market, which is more aligned to the initial ideas suggested by Kagermann et al., (2013).

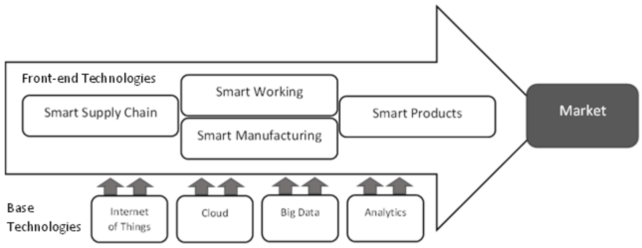


Figure 2.0: Theoretical Classification Framework

The article presented by Frank et al., (2019) provides some clear guidance for making sense of the complexities of Industry 4.0 and the ideas around integration being the clear differentiator. From the authors' article here, we can begin to segregate the technologies into their corresponding areas to provide a starting point in further clarifying understanding of the movement. Arguably, the smart technologies outlined above have their roots in advanced manufacturing (Frank et al., 2019), which is hardly a new concept. The ideas outlined within the smart section could then be used as an aid for evaluating where the business is with reference to the highlighted technologies. This form of diagnostic could then be used as a building block to engage operations on the journey to the digital future. It can also be used as a reference for understanding how far forward or behind individual business are in respect to the digital transition and therefore a part of readiness of maturity. Although further conceptual analysis is needed, this article provides clarification for understanding the interrelated technologies of Industry 4.0 along with guidance towards a possible starting point in planning for the adoption of these technologies.

Further developments in understanding Industry 4.0 have led to much ongoing debate within the academic community, with Buer et al., (2018, p. 3) suggesting that Industry 4.0 has evolved into a *"poorly define buzz word"* for developments in the next era of manufacturing. They argue that the phenomenon is nothing new but just an alignment of existing technologies. This notion is also supported by Kolberg & Zühlke (2015) and Drath & Horch (2014) who suggest that Industry 4.0 is a catchy marketing name for existing technologies. These uncertainties and ambiguities surrounding defining Industry 4.0 could stem from the number of terms and concepts that are associated with this evolving phenomenon. Smart manufacturing, the fourth industrial revolution, digital transformation and the real-time factory are all terms associated with Industry 4.0, but perhaps add to the confusion into clearly establishing an agreed upon definition (Culot et al., 2020; Erro-Garcés, 2019). The findings of studies by Culot et al., (2020) also suggest that Industry 4.0 is not a single breakthrough innovation but is made up of numerous evolving 'technological ingredients', which may be an additional factor adding to the ambiguity surrounding clearly defining Industry 4.0.

Additional factors then added to these ambiguities could include the explosion of literature surrounding Industry 4.0. These ideas are supported by Kamble et al., (2020) who present evidence demonstrating that since 2013 the number of publications surrounding Industry 4.0 has almost doubled year on year. The upshot has been the confused and disorganised body of knowledge currently surrounding Industry 4.0 (Sestino et al., 2020a). Considering the above literature findings, the author of this thesis offers a definition of industry 4.0 suggesting that Industry 4.0 concerns the *"aggregating and integrating the selected technologies* *for your business which bring around intelligent connectivity aligned to the strategic goals of your business operation”* (Bainbridge, 2023).

Arguably, the definition above suggests a non-revolutionary and a quite pragmatic approach to the puzzle in defining industry 4.0/digital manufacturing. In fact, the definition is built upon the work of Frank et al., (2019) which discusses the interconnection of the front-end and base technology groupings and moves away from the ideas around technology push to suggest that a selection of technologies are needed. These selected technologies are built from the needs of the business and are aligned to a strategic need, suggesting focus and clarity around business needs. This definition also provides clarity through the suggestion that Industry 4.0/ digital is not about single deployment of technology but a more aggregated and integrated solution is the difference between todays evolving industrial technology deployment and that of Industry 4.0.

2.1.3 Summary

From the very start of this research on Industry 4.0, there have been challenges in defining this phenomenon and it may be suggested that there are many reasons for this. Perhaps the starting point for the conceptual confusion are the observations of Kagermann et al., (2013) and Lichtblau (2015) who initially state that the possibilities of Industry 4.0 are so disruptive that they constitute a potential for a new industrial revolution. Such a viewpoint has gone on to create a movement of ‘band-wagoning’ academic, industrial and consultancy circles. Kamble et al., (2020) present evidence that since 2013 the number of publications surrounding Industry 4.0 has almost doubled year on year, resulting in a confused and disorganised body of knowledge surrounding Industry 4.0 (Sestino et al., 2020). These developments within the literature suggest it is difficult to pin down an agreed definition of Industry 4.0, so leading to further confusion and ‘noise’. These ideas about developments in the next era of manufacturing are present in the revolutionary ideas and concepts of both Kagermann et al., (2013) and Lichtblau (2015), moving onto the latest trends in manufacturing outlined by Kamble et al., (2020), and then to Buer et al., (2018) in their suggestion that

Industry 4.0 has evolved into a "poorly define buzz word". Here Kolberg & Zühlke (2015) and Drath & Horch (2014) also suggest that Industry 4.0 is a catchy marketing name for existing technologies which could add to the confusion in clarifying this phenomenon.

Arguably the aforementioned authors - Culot et al., (2020), M. Hermann et al., (2016) and Pereira & Romero (2017) - offer a perspective that takes 'Industry 4.0' to be an umbrella or collective term for the introduction of a broad range of technologies into industry. The proposition here is that rather than being static, the Industry 4.0 phenomenon is still evolving, and in much of the literature these ideas are merely conceptual. The Industry 4.0 movement is fluid and while the technology evolves and the aggregated effects begin to be realised, some agreed definition might be confirmed quantifiably if the movement is evolving at such a pace.

The umbrella concept then to be taken from the aggregated literature reviewed here is that Industry 4.0 is largely concerned with the integration of IT into the value chain through interconnected devices which manage, control and exchange data. This is a concept still in evolution as it integrates existing industrial technologies with recent developments in digital technologies to allow an aggregated, interconnected network of data-controlled devices which collaborate intelligently in allowing the exchange of data and real-time decision-making based upon changing operational factors. Further clarification of what makes Industry 4.0 different might then be provided by the metaphor of an 'industrial ecosystem' where collaborative technologies interact, make decisions, provide feedback on performance and constantly push the boundaries of improved performance and effectiveness. Within this concept of an industrial ecosystem, today's industrial technologies are interconnected and aggregated through the digital technologies of Industry 4.0 which evolves the manufacturing system. The article presented by Frank et al., (2019) thus provides clear guidance of how to make sense of the complexities of the overall system where we can begin to segregate the technologies into relative categories which provide further clarification and understanding of the movement.

A further solution can be proposed in clarifying the evolution of the Industry 4.0 concept by developing the discussions around technology aggregation. Today's industrial technologies are in abundance within the workplace, from the automatic guidance vehicle (AGV), vision systems, programmable logic controllers (PLC's) to increased manufacturing automation, with each tool arguably designed to solve a specific workplace problem but often operating as a standalone technology. The concept of Industry 4.0 hence suggests that the revolutionary idea at play is the aggregate of all these technologies connected to intelligently integrated communications systems.

2.1.4 Industry 4.0 and Smart Factories

As previously highlighted, defining Industry 4.0 has not been an easy task. Terms such as 'smart manufacturing' and 'factories' appear to be used interchangeably with 'Industry 4.0' and are arguably synonymous (Kang et al., 2016; Nosalska et al., 2019). In order to crystalise the two phenomena, the following sections will briefly introduce the concept of the smart factory before the similarities of Industry 4.0 and the smart factory are identified.

With regard to the smart factory, there is some consensus in the research literature about the introduction of the Industry 4.0 technologies will lead to smarter factories and smarter ways of working in the context of Industry 4.0. Indeed, the relationship outlined by some authors is one of cause and effect, since the introduction of the connected technologies will lead to smarter operations (Hozdić, 2015; Kagermann et al., 2013; Lu, 2017; Stock & Seliger, 2016). According to Sander et al. (2016), smart manufacturing and intelligent factories are the goals of Industry 4.0 (Sanders et al., 2016b), while Kamble et al., (2020) suggest that Industry 4.0 transforms existing manufacturing system into smart manufacturing systems. Stock and Seliger et al., (2016) then describe smart manufacturing in terms of the sensor-driven autonomous data processing taking place between all the tools and equipment involved in the production process. These sensors send, receive, process, decide and act upon data within the workplace, while the system is monitored either by a master software model or by a human following a sophisticated computer program. Finally, Lichtblau (2015) suggests the smart factory is an environmentally-friendly ecosystem, where autonomous production systems organise themselves not through human intervention but through the integration of cyber physical systems which link the virtual and physical world together through the internet of things.

It is feasible to conclude from the introductory paragraph of this section that the similarities of between Industry 4.0 and the smart factory are indeed observable. Sander et al., (2016b) suggest that the goal of Industry 4.0 is the smart factory which could suggest a cause-and-effect relationship. These ideas are also supported by many including Hozdić, (2015); Kagermann et al., (2013); Lu, (2017); Stock & Seliger (2016), while one of the early authors on Industry 4.0, Litchtblau (2015), opts to use the term 'smart factory' when describing Industry 4.0.

On the other hand, Kusiak (2018) reports that smart manufacturing has its roots in the US and Japanese intelligent manufacturing of the 1990's on whose basis industrial research developed an intelligent manufacturing system programme (IMS). Kusiak (2018) also recognises that the evolving nature of manufacturing has led to recent developments in the internet of things which, when integrated with cyber physical systems, have led to a new concept embraced by industry. Here the author offers visions of a smart factory by listing six pillars of smart manufacturing which he nonetheless recognises are neither exhaustive nor static. In fact, these pillars have been around throughout history with their names and importance changing over time.

Here, Kusiak (2018) takes the example of big data used in the era of smart manufacturing, arguing that data was an integral part of manufacturing before being called big data in the current era (Kusiak, 2018). This notion of evolving manufacturing is then supported by ten conjectures employed to capture the essence of smart manufacturing, supported by evidence in research papers going back to the 1980s where there was discussion of similar concepts such as intelligent automation. Kusiak (2018) recognises the similarities with previous technology in Industry 4.0 by presenting evidence from Thoben, Wiesner and Wuet (2017). Clearly, similarities exist between what is described within the previous paragraph and what has been uncovered from within the definition section of this literature review. The internet of things, cyber physical systems and the use of big data are all elements of the base technology category proposed by Frank at al. (2019). What might then be suggested here is further evidence that Industry 4.0 and the smart factory are in fact synonymous.

Osterrieder, Buddde and Friedli (2020) then present further evidence that smart manufacturing is the American version of Industry 4.0 and that both have at their core similar technologies, methodologies and trends. These authors then present an adapted technical concept of the smart factory through the introduction of four distinct layers - physical, data, cloud and intelligence, and the control layer – in a schema which is also supported by Trappey et al., (2017) and Wang et al., (2016). The physical layer is the transformation layer where the inputs of worker, material and machine are transformed into the quality products needed by the customer at the right time and at the right cost. The data layer is where machines and sensors communicate and transfer information to the cloud, while the cloud communicates this back in the form of information through sophisticated analytics. As suggested, the control layer is where supervision takes places through smart factory programmes and human intervention (Osterrieder et al., 2020). The authors then present a comprehensive literature review consistent with their view that the smart factory contains ‘essential elements’, including machines communicating with each other through sensors, and actors who can understand and interpret data to allow the operational achievement of predefined tasks, managed and monitored by a higher-level sophisticated computer programme which is represented within the layered approach discussed earlier (Osterrieder et al., 2020).

As with much of the research on the digital evolution outlined here, there seems to be uncertainty surrounding the term ‘smart factory’. One school of thought from authors such as Henning (2013), Hozdić (2015), Kamble et al., (2020), Lu (2017), Sanders et al., (2017) and Stock & Seliger (2016) is that Industry 4.0 and smart manufacturing have a cause-and-effect relationship and by implementing Industry 4.0, the new digital technologies will lead to smart and more complex factories (Kagermann et al., 2013, p. 19). By connecting existing and new technologies together in a self-contained, self-managed and self-regulated ecosystem, it might be envisaged that the notion of the smart factory is in constant evolution. This concept of constant evolution would then be supported by the constantly evolving nature of emerging computational and digital technologies alongside advancements in AI.

Interestingly, Napoleone et al., (2020) define the concept of the smart factory as having as its key characteristic the capability to evolve constantly (Napoleone et al., 2020). On the other hand, Kusiak (2017) and Osterrieder et al., (2019) state that the smart factory is the American version of Industry 4.0. Kusiak (2017) presents a vision of the future based upon the evolutionary developments within manufacturing which he calls smart manufacturing, presenting evidence of very similar concepts, visions and technologies to that of Industry 4.0. The definition of smart manufacturing by the National Institute of Standard and Technology (Kusiak 2017, p. 2) also presents out similarities to Industry 4.0, which would support the concept suggested by both authors. Kusiak (2017) also develops this notion of manufacturing passing through an evolutionary concept rather than the revolutionary concept suggested by many.

2.1.5 Industry 4.0 and Smart Factories - In Summary

Going by the evidence given previously, one school of thought is that the terms ‘Industry 4.0’ and ‘smart factories’ can be used interchangeably to describe the next evolution in advanced manufacturing systems enabled by digital technologies. Authors such as Nosalska et al., (2019) and Kang et al., (2016) suggest that Industry 4.0 and smart manufacturing are perhaps synonymous. Kusiak (2018) suggests that smart manufacturing has its roots in US intelligent manufacturing of the 1990’s, which was the American version of Industry 4.0. Gillani et al., (2020) also suggest that Industry 4.0 is powered by digital technologies transforming traditional factories into smart factories, which is also an idea supported by (Kagermann et al., 2013, p. 19). Frank et al., (2019) suggests that smart manufacturing is a central pillar in conceptualising Industry 4.0.

To add clarity to this thesis as suggested in the previous section, developments around this relationship between Industry 4.0 and smart factories is indeed one of cause and effect. The effect of advancements of digital transformation will hence enable new, improved and smarter ways to manufacture products across the entire value chain. For the purpose of bringing clarity to this thesis, we will assume from now on that the terms ‘Industry 4.0’ and ‘smart factories’ have the same meaning. This will allow clarity in the debate over defining what Industry 4.0 is and its potential impact.

2.2 The Technologies

Previous sections have suggested that with its emerging nature and integration with existing industrial technologies, defining Industry 4.0 and its technical complexities is no easy task. Furthermore, a same similar problem might be experienced with the technologies associated with Industry 4.0. Advancements in robotics and their integration with humans (cobotics), industrial autonomous vehicles, widespread industrial automation, simulation and advancements in computing are all technologies and applications associated with Industry 4.0. Culot et al., (2020) have reviewed the research of Chiarello et al., (2020) to conclude that the technological landscape is still evolving and that over 1000 individual technologies underpin the movement within 30 different disciplinary fields. The research literature then reports ten principal enabling technologies at play here: augmented reality, blockchains, advanced robotics, simulation, additive manufacturing, vertical and horizontal system integration, big data analytics, cloud, cyber physical and the internet of things (Culot et al., 2020, p. 3).

As discussed earlier, the study presented by Frank et al., (2019) proposes a theoretical framework to categorise the technologies associated with the movement into front-end and base technologies. Arguably, the front-end technologies of smart supply chain, smart working, smart manufacturing and smart products are nothing new for today’s industry and many of them are currently in working operation. The intention of this section is thus to provide a general overview of what Frank et al., (2019) describes as the base technologies of cloud, big data and analytics, as well as the industrial internet. Lin et al., (2018) suggest that as digital technologies, cyber physical systems, cloud computing and the internet of things are mainly associated with Industry 4.0, while cyber physical systems should arguably be included within the literature review as Kagermann et al., (2013) suggest that Industry 4.0 is built upon cyber physical systems. Given that the creation of a cyber physical system was one of the original ideas of Industry 4.0, then an overview will be included within this literature review. The recommendation then is that cyber physical systems be added to the conceptual model developed by Frank et al., (2019).

Being that the focus of this research project is to understand the level of knowledge, adoption and impact of Industry 4.0, this section within the thesis on Industry 4.0 technologies will provide only a general overview of the technologies outlined. This section is designed to understand more about what these technologies are rather than evaluate the technical details behind the technologies themselves.

2.2.1 The Cloud

The US NATIONAL INSTITUTE OF STANDARD TECHNOLOGIES (NIST) defines cloud computing as "*a model for enabling ubiquitous, convenient, on demand networks access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction"* (Wang et al., 2015). The main ideas around cloud computing shift from the traditional process of expensive inflexible servers driving in-house computing systems to cloud-based IT infrastructure of aggregated networks and data storage systems capable of flexible software and data-managed solutions. Now such cloud-driven IT systems are outsourced to third parties where everything is treated as a service - either as software services (SaaS), the platform as a service (PaaS) or infrastructure as a service (IaaS) - but all providing distinct flexibility when compared to traditional in-house IT systems (Xu, 2012).

Flexibility and benefits can come in many forms including cost reduction as the system has a pay-as-you-go model with increased flexibility due to system availability and increased productivity (Xu, 2012). Examples of cloud computing are a part of everyday life, from cloud-based entertainment such as Netflix or software programmes such as Lucidchart, to the service deals available today for mobile phones. Moreover, they have become a very disruptive innovation for some industries in the positive sense.

Cloud manufacturing can be defined as the *“execution of a specific application with data transferred over the internet, stored and processed over a pool of distributed hardware, system, and software resources”* (Wang et al., 2015). Helo et al., (2021) suggest that cloud manufacturing transforms manufacturing capabilities (such as production) as well as performance management and manufacturing resources such as software and hardware into cloud-based services for different stakeholders. These authors also suggest that the entire business of manufacturing can be realised on the cloud, including converting manufacturing resources into an on-demand manufacturing service. This service can subsequently connect customers and manufacturers to co-create individualised products and services (Helo et al., 2021).

As highlighted previously, Xu (2012) notes that the services offered through cloud computing services include software as a service (SaaS), platform as a service (PaaS) and infrastructure as a service (IaaS). Meanwhile, Helo et al., (2021) present several applications for manufacturing as a service (MaaS) including production planning, process monitoring and product delivery, as well as selling machine capacity such as 3D printing, supply chain visibility and collaboration, and manufacturing execution systems which can serve multiple factories (Helo et al., 2021, p. 5). Moreover, this list of possibilities is not exhaustive as MaaS offerings could also include predictive analytics for maintenance, including robotics, digital twin research and development and the possibilities of product design in some areas of industry.

The implications could be significant for small to medium-sized enterprise (SME) with this type of pay-as-you-go technology model. The model has the potential to reduce major capital investments for SMEs, providing low-cost access to disruptive technologies which might traditionally have been out of reach for the smaller organisation. Giving access to today’s technologies to the owners of small businesses has then the potential to open new business streams through new services or products and so get closer to the customer in the automotive tier structure.

As with cloud computing, cloud manufacturing also presents significant potential to disrupt certain parts of the manufacturing and automotive industry both from an OEM and SME perspective. However, several barriers to entry might inhibit wide-scale adoption of aggregated cloud technologies. Cyber security, for one, might be something which the service providers would need to address on the part of the potential adopters of cloud-based technologies, while the apprehension of organisational leadership before the unknown may also hinder adoption efforts.

On top of the fear of new technologies are the complexities of understanding the technologies themselves. For many, this level of technological complexity might inhibit the rate of diffusion. As an example, what they are trying to achieve with technology adoption is how to leverage the best out of the collaborative technologies (Helo et al., 2021). The legacy systems currently operating within businesses may be an additional factor slowing the adoption efforts of today's cloud-based technologies, added to this issue the questions around existing IT infrastructure capability and readiness.

Sitting alongside these potential barriers to technical execution may also be the issue of how much of the actual manufacturing can be executed as a service, but this is a very big question that falls outside of this thesis. However, there are signs that disruption is beginning to occur - to take the example of the Swedish electric truck company Volta, who are now offering TaaS as a 'Truck as a Service' proposition for clients (Volta Trucks, 2022). Volta's original idea was to utilise under-capacity in automotive manufacturing to force manufacturers to build the truck on behalf of the company, but the reality is still very different as the company has still had to perform such operations themselves (Prez, 2021).

2.2.2 Cloud Summary

Within the context of modern manufacturing, the cloud has the potential to be a significant disruptor. It can be argued that the potential is only limited by our own imagination, as recent history cloud-based systems have certainly disrupted to the extent that Joseph Schumpeter's (1883-1950) ideas on creative disruption are still very relevant today. The shift to digital online entertainment has seen organisations such as Blockbuster movies and similar independent organisations cease trading. The operations of various cloud-based platforms as a service (PaaS) may be disruptive in this context, but the cloud can also bring low-cost solutions which provide technological capability for many. Clouds might then provide flexibility and accessibility for organisation who may not traditionally have had access to this kind of capability. As with many technological developments, barriers might exist but arguably this is no different with the cloud either.

2.2.3 The Internet of Things

Arguably, the application of the internet of things is currently breaking through into people's everyday lives. Some examples might include the remote management of things, such as household heating systems. These are intelligent connecting devices accessed through the cloud but not directly controlled by humans rather through the 'internet of things' (Pătru et al., 2016). Both the internet of things and smart devices allow communication between each other or the user via the internet (Pătru et al., 2016). In essence, the internet of things turns common objects into connected devices through ubiquitous connections to the internet (Sisinni et al., 2018) which might be the foundation for understanding the complexities of IoT in a relatively ordinary everyday environment.

According to Gilchrist (2016), the term 'the industrial internet' was first used by GE (General Electric), while other major companies such as Cisco used the term the 'internet of everything'. To clarify these terms within the concept of the internet of things (IoT), we first need to recognise the differences and here Gilchrist (2016) suggests that the industrial internet and the general concept of the internet of things have a very different target audience because the technical requirements and strategies needed to fulfil the needs of industry are very complex. Therefore, the following chapter will be broken down into two main research areas initially beginning with an analysis of the internet of things, followed by further analysis of the industrial internet.

Leloglu (2016) presents the definition of IoT suggested by the international telecommunication union: *“The internet of things is the global infrastructure for the society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies*” (Leloglu, 2016, p. 122). The internet of things integrates cyber physical devices such as actuators, sensors and RFID to allow decisions to be made which are hoped to lead to a smart way of working (M. Hermann et al., 2016). The transfer of this continuous data flow through wireless and wired networked platforms is then interpreted to enable an understanding of complex environmental conditions, allowing decisions to be made without human intervention (Leloglu, 2016). At its fundamental level, this means the collection and exchange of information via the connection of physical objects to the internet through a ubiquitous network and the interoperability of those exchanges (Trappey et al., 2017).

Sestino et al., (2020) suggests that the term ‘internet’ refers to a vision of technology which is virtually network orientated, while “things” are the objects to be integrated into a technological framework. The authors also present five different definitions of the internet of things (Sestino et al., 2020b, p. 2). Sestino et al., (2020) then present a comprehensive literature review which focuses upon the use of internet of things and big data as enablers for digital strategies. Here the research breaks down the currently evolving strategies and narrows the focus to improve business processes, business management and innovation, looking critically at current business models and culture, privacy and ethics and marketing strategies. Such studies also suggest that the internet of things might warrant studying data such as consumer behaviour, attitude and choices to transform products and services into opportunities and increase overall business competitiveness (Sestina et al., 2020).

From the perspective of process improvement, Sestino et al., (2020) suggest that the internet of things can support the reshaping of production processes operationally, as gathering large amounts of ‘big data’ can support managerial efforts in strategic planning. The author present evidence from Dwivedi et al., (2019), Chui et al., (2010) and Liu et al., (2017) demonstrating that the large amounts of real-time ‘big data’ gathered by the internet of things too large for traditional data processing software is instead used to monitor, intervene and change production methods so leading to improved efficiencies and cost reduction. Here the authors suggest that this digitalisation of marketing and management strategies changes business competitiveness, entailing that the alignment of the internet of things and big data is frequently understood to be the fourth industrial revolution (Sestino et al., 2020, p. 3). According to this study, the 'smart' internet of things devices then allows autonomous operations and self-optimisation resulting in a self-nurturing knowledge allowing an effective and efficient decision-making process.

Although Sestino et al., (2020) present an interesting case for the benefits of the internet of things and big data, they recognise that organisations need to review the implications of data privacy and ethics to ensure the protection of consumer data. In this sense, they conclude that the firms need to consider there is a balancing act to be maintained between the evolving desire for pushing innovations with that of the ethical norms of consumers (Sestino et al., 2020).

According to Civerchia et al., (2017), the industrial internet is laying the foundations for smart cities, smart homes and now smart factories. Smart homes involve the installation of detection and control devices like switches and sensors such as security systems, lighting, ventilation, heating and air conditioning (Alaa et al., 2017) as home innovations dependent on the internet of things to change human lifestyles through their own technological time. More practically, the potential impact of these disruptive devices may be significant in terms of improving home safety, energy utilisation and management, security and even in the management of carbon footprints (Alaa et al., 2017).

In turn, Sestino et al., (2020) present evidence of how the internet of things and big data can affects organisation and their digital strategies positively but only briefly mention the potential negative implications of the movement. The potential implication for the internet of things and its collaboration with big data is arguably the occurrence of more barriers to entry or barriers to full-scale adoption than initially highlighted within this study. As the internet of things becomes an everyday part of human life, concerns are growing about cybercrime as a barrier to a full-scale adoption of web-based technologies. Atlam et al., (2020) go as far as to suggest that cybercrimes might affect human life due to their amalgamation with the everyday life of people (Atlam et al., 2020). Gilchrist (2016) also presents findings which support the risk of cyber security being so great that 66% of IT professionals consider it to be the main barrier to adoption for their organisations (Gilchrist, 2016). At first glance, this uncertainty could potentially lead the everyday consumer to move away from the adoption of the technologies. However, Aggarwal et al., (2020) present evidence from a relatively small Cisco survey which reports that only 9% of the 3000 consumers surveyed about the ‘internet of things’ believe that the system will keep their data safe, with 53% believing that the value the internet of things brings to their lives outweighs the risks entailing that they are not willing to move away for using their devices. Cisco has termed this seemingly irrational phenomenon the Internet of Things (IoT) Value/Trust Paradox.

As has been outlined, the potential privacy and security threat of IoT-based technologies may be significant in terms of inhibiting widespread adoption of this new ability to connect everything to the internet, particularly within an industrial setting. Given real security concerns about the interconnecting elements creating vast amounts of data (Arora et al., 2019), the threats, flaws and vulnerabilities of the system are potential question still needing to be answered.

The term ‘the industrial internet’ was first coined by GE (the US General Electric company) to describe an improved way to create better visibility in company operations achieved through the integration of cloud computing and storage to provide access and feedback of operational results through machine sensor technologies and data sets using advanced data analytics (Gilchrist, 2016). This cloud technology provides improved operational performance, efficiency, productivity and reduced unplanned downtime leading to improved profits for an organisation (Gilchrist, 2016). The term ‘industrial internet’ hence integrates the industrial development and the developments of the internet with the connection of equipment, people and data analysis in an open, global network (Qin, Chen and Peng 2020).

Alaa et al., (2017) also stress that the industrial internet will lead to higher levels of operational safety, productivity and efficiency, and ultimately to smarter factories. Safety improvements can then be achieved through deeper knowledge of workers' position within the operation thanks to the constant collection of data. Productivity improvement will then result from an increase in automatic processes and efficiency through the reduction of equipment failures achieved by fast fault detection and prevention capabilities. Developing this idea further, the authors then conclude that device communication and interoperability capabilities will allow predictive data management to shift maintenance functions away from a reactive to a predictive maintenance culture which will then reduce maintenance costs and avoid potentially dangerous situations (Alaa et al., 2017).

Similar to the research presentation of Osterrieder, Budde and Friedli (2019), Trappey et al., (2017) use layering as a form of classification with which to identify the optimal industrial application of the internet of things and suggest a four-layered approach to the industrial architecture. Starting from the bottom layer and working upwards, the perception layer deals with sensor and actuators to detect temperature, vibration, acceleration, weight, motion and humidity. The layer above the perception layer is the transmission layer which transfers the data to the upper layers. The big data analytics and cloud computing take place in the computational layer which derives meaning from the data by processing it and making corresponding decisions to be delivered to the top layer, which is the application layer. The application layer hence provides the tactical know-how for the cyber physical systems. As highlighted within the definition section of this literature review, this notion of tactical intelligence is perhaps the key to understanding how these integrated digital technologies collaborate with existing industrial technologies, providing clarity around the whole subject of Industry 4.0.

In turn, Boyes et al., (2018) underline the ability of the industrial internet to analyse data through physical and digital applications, adding weight to the argument that big data analytics is the foundation of the industrial internet. Big data analytics involves the advancements in analytic techniques which operate on big data sets. Big data analytics thus concern two principal elements (big data and analytics) which, in their conjunction, have created one of the most profound trends in business intelligence today (Russom, 2011). In turn, Trappey et al., (2017) suggest that there are key challenges for the implementation of the internet of things, concluding the recognition that the new protocols needed for the internet of things will be hindered by the legacy systems currently in operation within industry. Developing these findings further then, it should be recognised that due to the investments needed the shift from old to new systems is a potential barrier to the adoption of wider spread deployment especially within the small to medium-sized business sector.

2.2.4 Internet of Things - Summary

One can argue that the term ‘internet of things’ is something that is often used but perhaps misunderstood to a point. There are some clear benefits to the everyday usage of the internet of things which have been discussed above. Although the application of the technology in an industrial setting can then be complex, it is arguably another key ingredient in connecting and monitoring the collaborating and aggregated technologies within the smart factory. The potential of this data for monitoring and analysis can then lead to the optimisation of industrial operations (Sisinni et al., 2018). It may be suggested that this ‘purist’ view of integrating these technologies is significant in the case of real-time monitoring systems connected to aggregated technologies which are constantly learning. This interconnecting and learning from the cloud manufacturing systems discussed above might ultimately become revolutionary, but the reality today may also be different. Is this level of integration and monitoring control feasible within an industrial setting? Perhaps the suggestion is that much like the connectivity within a conceptual ecosystem, everything should be connected in order to realise its full potential but the presence of cyber-crime as a major factor hindering adoption needs to be addressed prior to any successful integration.

2.2.5 Big Data and Analytics

As technology evolves in the workplace so does the amount of data that may be extracted from it. The process of receiving, storing, organising and managing this ever-increasing quantity of data, then converting this raw data into useful information, is what is known as big data and big data analytics (Lee et al., 2015;

Xu & Duan, 2019). In essence, big data is a term or technique referring to the processing of large quantities of data (Lee et al., 2015; Xu & Duan, 2019) which also encompasses the security and privacy of data, the capture, transfer and store of data and the analytics behind the transformation of raw data to information.

Russom (2011) suggests that big data analytics refers fundamentally to advanced analytics operating in big data sets (Russom, 2011). Xu and Duan (2019) then present a breakdown of big data from a dual perspective, involving both system infrastructure and data analytics. System infrastructure is the real-time communication between facilities and cyber devices, involving data capture, data storage and retrieval, and distributed computing (Santos et al., 2017). Within this context, data capture is the raw data coming from devices such as vision systems. The processes of data storage and retrieval refer in turn to the shift away from traditional databases to the greater use of data warehouses (Santos et al., 2017), which are specifically designed to store a vast amount of data. Here the authors suggest that as these data warehouses are so vast the capabilities of a common computer to process the data will no longer be sufficient, entailing that a supercomputer or a cluster of computers will be needed to do the task (Xu & Duan, 2019). The authors also stress that to make the collection and storage of big data work, a robust system is required meaning one providing security, resilience and reliability. Their conclusion is that failure within any one of these areas could collapse the entire system.

Data analytics is also used to gain insights from data. Here we can take the example of how data can be turned into information while recalling that descriptive, predictive and prescriptive data analytics are then required to perform the task. Descriptive analytics is a statistical function used to analyse data to establish calculations, such as mean, variance and median and other more sophisticated statistical methods (Xu & Duan, 2019). Here, base line analytics are often used to determine the current situation, while predictive analytics draws upon past statistical patterns to predict what can potentially happen in the future. Finally, prescriptive analytics build upon predictive analytics to propose actions based upon the predictive outcomes. To make these operations work, the authors suggest that the system needs to be capable of self-awareness and able to maintain itself (Xu & Duan, 2019).

The complexities surrounding data analytics and the amount of data to be processed has led to the defining characteristics of big data. Cui et al., (2020) present what they describe as ‘5V characteristics’: volume, variety, velocity, value, and veracity. Volume relates to the quantity of the data; variety is the various types of data coming in from the different data sources; velocity is the speed of the accumulating data; value is the added value brought by the data; and veracity refers to the inconsistencies within the data sources (Alcácer & Cruz-Machado, 2019; Cui et al., 2020). As with much of this Industry 4.0 movement, there has been some debate over the characterisations of big data, and here (Amanullah et al., 2020) present 6V’s characteristics while Alcácer and Cruz-Machado (2019) present ten characteristics.

The vision for big data analytics proposed by Santos et al., (2017) is to create an integrated environment which supplies real-time data to support operational decision-making through the collection, storage, processing and analytical distribution of data to support the needs of the factory of the future. The authors further develop this concept and suggest that the evolving nature of big data has shifted from basic data to data used for business intelligence purposes. Cui et al., (2020) then suggest that the opportunities for big data within manufacturing of the future is vast. They support this proposition by presenting evidence from internet companies such as Facebook, Google and Yahoo which have utilised big data in the form of search engines and data analytics to deliver greater efficiency to business.

However, to consider the impact of big data within industry as a positive could benefit organisations in several different ways. To take one example, the use of predictive analytics within maintenance (Dalzochio et al., 2020; Sahal et al., 2020) could assist with the shift away from reactive maintenance to preventative and predicted maintenance. The use of data analytics in the context of lean manufacturing and the six sigma (Buer et al., 2018; Kamble et al., 2020) could then assist organisations in their journey to make their manufacturing processes more efficient. Sestino et al., (2020) suggest that big data represents disruptive revolution in decision-making. The use of this operational transformation process (Slack et al., 2010) to integrate all the potential data sources through the supply chain to customer and on to the end-consumer then has the potential to provide deep organisational learning. The benefits for organisational intelligence might then constitute a major advantage in the expanded usability of big data.

The concept of big data and intelligence can be traced back to 1958, where an IBM researcher called Hans Peter Luhn has proposed that business optimisation can be conducted through data (Santos et al., 2017). Other researchers Xu & Duan (2019) agree with the notion that big data is nothing new as the present issues date back to the 1980’s with the stock exchange, particle physics and human genome concerned with big data usage. Although the concept of data analytics is not new, what these authors underline is the size of the data involved from the use of Terabytes in 2005 to Petabytes in 2010 and Exabytes or Zettabytes in 2017, as measurements are usually defined by the amount of data processed within a tolerable amount of time beyond a commonly used computer (Xu & Duan 2019). Cui et al., (2020) have developed this concept further to report that the future of manufacturing cannot be achieved through traditional software and technologies, so presenting two main issues about why this is the case. The first problem is the lack of integration due to the existence of different vendor interfaces, while the second issue is the lack of traditional software, sensory capabilities and a corresponding inability to respond quickly to dynamic changes (Cui et al., 2020).

Sestino et al., (2020) suggest that big data is still evolving and that some firms are yet to capitalise on big data and the internet of things. As highlighted earlier, (Kusiak, 2018) also reports that data gathering and analysis have been a fundamental part of manufacturing for years, suggesting that the evolving aspect of this movement is the quantity of data produced. Santos et al., (2017) also suggest that the notion of big data can be traced back to 1950’s which again supports the idea of an evolving technology. As with most web-based solutions, other concerns for big data analytics are the challenges surrounding security, privacy, expense, ethics and the ever-increasing governmental regulations associated with data management.

It might be suggested that the evidence presented above supports the idea of evolutionary development rather than big data being revolutionary within the context of Industry 4.0. The use of workplace data is nothing new and it could be argued that the issues which currently exist within the workplace will only get bigger with the ever-increasing amount of data in use. In his 17 years of industry experience, the researcher has uncovered many problems with how data is used within the workplace. These issues may include accuracy, how the data is used and, more to the point, how it is displayed, as well as issues to do with data storage and legacy systems and recent developments in data protection. In fact, it is not uncommon to find that when data is used within the workplace, what is uncovered and what is displayed to management are very different phenomena.

Guerreiro et al., (2019) present a complex paper on the difficulties and challenges of managing these high volume, high variety and inconsistent data sources (veracity) alongside multi-sourced and multi-structured data sets. The authors recognise that gaining useful insights into the data generated by the system in a timely manner is one of the main challenges for the usability of big data and its analytics. The authors then present a case centred upon the Volkswagen plant located in Portugal and propose a solution to the above problems through a reference architecture. While recognising the contribution of these authors to understanding big data and its complexities, their thesis does not evaluate this architecture as by nature it is a shift away from the theme of the research.

However, Guerreiro et al., (2019, p. 2) present some interesting research introducing the swarm intelligence paradigm to think about how a distributed, scalable and self-adaptive processing approach operates. They define swarm intelligence as *"a collective behaviour of decentralized, self-organized systems, natural or artificial, where individual agents make cooperative efforts to produce a useful behaviour, acting asynchronously in parallel".* The authors then make the analogy of the colonies of animals seen in nature.

2.2.6 Big Data and Analytics - Summary

It has been suggested in the literature that the ideas around data and analytics are nothing new as the potential of data analytics has always existed. How the data is used within the context of manufacturing arguably has huge potential, but the reality could be much different given the reasons outlined above. However, advanced analytics operating in big data sets (Russom, 2011) may well have some significant potential value for organisations. The advanced analytics and artificial intelligence systems able to learn machine-operating systems have the potential to cause a positive shift in operational performance. There is significant potential in ideas around data lakes and large storage system along with the advanced analytics accompanying these advances. If used correctly, the opportunities that big data can bring in terms of operational excellence and six sigma then have the potential to advance operational performance.

As well as the positives associated with big data, there are also some potential uncertainties. The quantity of data involved has the potential for misuse, as in the case of Cambridge Analytica's illicit data mining. As with many technological advancements, cyber-security concerns may then arise as has been highlighted above in the case of the usability interface. The upshot is that if data sets are not utilised in industry today then the scale of the data and the associated analytics may not make any significant difference.

2.2.7 Cyber Physical Systems

Cyber physical systems describe a broad, complex range of next generation, physical-aware engineered system able to integrate computing technologies (cyber part) into the physical world (Gunes et al., 2014). Cyber physical systems (CPS) are collaborative computational technologies connected to the physical environment (Napoleone et al., 2020). They access and process data relating to themselves, evaluate this data to connect and communicate with other systems and then make decisions and act upon the decisions made (Napoleone et al., 2020). Equipment such as sensors, actuators, devices, machines and robots transfer data between them to create actionable operations, which form the basis of smart industrial communities (Garetti et al., 2015). The function of cyber physical systems in a manufacturing facility entails a self-organised factory where industrial applications communicate with each other, making decisions which lead to a smarter way of manufacturing products. Monostori (2014) further develops this notion by describing CPS as autonomous and cooperative sub-systems connecting with each other in situation-dependent ways on and across all levels of production, from machines processes through to production and logistics networks.

Gunes et al., (2014) suggest that the term ‘cyber physical system’ was first used around 2006 at the National Science Foundation in the United States (Gunes et al., 2014, p. 42-43) The authors also report that since 2007, CPS has been at the forefront of the US national research agenda. Within Europe, the Horizon 2020 innovation programme covering CPS, advanced computing research and innovation has attracted a budget of almost 20 billion euros. Here the authors provide rich insights into CPS from various perspectives from within the scientific community (Gunes et al., 2014, p. 42-43).

In turn, Romero-Silva & Hernández-López (2020) suggest that due to the relative newness of cyber physical systems, little information on implemented CPS technologies has been made available and a common definition is yet to be established. However, they do present key characteristics of the CPS which are supported by several other authors. To achieve autonomous decision-making and improve the overall performance of the manufacturing process, Romero-Silva & Hernández-López (2020) present several key characteristics which include sensors used to control and supervise the manufacturing processes, physical shop-floor components embedded with information systems, high levels of production automation and a network that communicates with the physical components and the manufacturing processes. The combination of these technologies along with the internet of things allows the cyber physical factory to achieve its aims of improving operational performance (Romero-Silva & Hernández-López, 2020).

The goal of the CPS is to allow manufacturers to create flexible, high efficiency low-cost production achieved through physical and computational components working together to implement processes in real time (Lozano and Vijayan, 2020). Garetti et al., (2015) agree that some of the key benefits of CPS within the factory are improved productivity, flexible manufacturing, agility and greater responsiveness to changing customer demands and reduced lead time, all of which can be achieved through improved plant optimisation, improved maintenance practices and a more predictive, detection-based approach to managing operational anomalies and improving machine reliability. As all these enabling technologies create the foundations to the smart factory, Napoleone et al., (2020) argue that the industrial potential of CPS applications can be as significant as its use as a building block on the journey to the smart factory.

Applications of CPS have been active in such areas like transportation, smart home, robotic surgery, aviation, defence and critical infrastructure (Monostori et al., 2016). The manufacturing and logistics sectors also benefit from applications such as autonomous cars, connected logistics, problem-solving robotics, automatic guidance vehicles, automatic storage and retrieval system (Wang, Törngren & Onori, 2015). More recent intelligent developments within society coming from the automotive industry are the introduction of driverless cars, and while there is increasing debate around their suitability, the technology continues to develop, while this concept is on the agenda for many automotive manufacturers. Romero-Silva & Hernández-López (2020) suggest that the impact of CPS on production scheduling may lead to a competitive advantage for organisations who adopt these technologies. The new capabilities of shop-floor data gathering, automation and sensor communication will then allow the resources to be utilised in the full production process.

While the authors Wang, L., Törngren, & Onori (2015) present some good ideas regarding the possibilities of CPS, one problem is that many of their propositions are still conceptual. What is presented here is a very idealised view of the possibilities that the CPS and the integration of other technologies present to manufacturing production control, which the authors have recognised within their research (Wang, L., Törngren, & Onori 2015). Certain existing demand-based technologies are available in today's manufacturing, such as storage and retrieval systems, but to have a fully automated demand-based system could present several challenges in changing schedules immediately based upon operational conditions. The cost of such systems could be a barrier to entry for many manufacturers, especially for smaller businesses. The scheduling of constant adjusting operations may also be costly in terms of stock-holding, due to the extra resources required to purchase the material.

Gunes et al., (2014) recognise that CPS has significant potential but also acknowledge that a number of key challenges also exist. Here the authors present six key challenges along with their associated attributes and their applications; namely, interoperability, predictability, reliability, sustainability, dependability and security (Gunes et al., 2014, p. 4254). It may be argued that acceptability could be an additional challenge for managers and business leaders. There has also been an ethical debate about the widespread adoption of factory automation. What then happens to the manufacturing and labour markets when adoption of the industrial and digital applications is introduced? Will the consequence be job losses or improved skills development for workers? This debate is covered within a later section of the thesis. For the moment, it is worth considering that one other significant challenge is the complex nature of CPS and how it integrates with the other technologies.

2.2.8 Cyber Physical Systems - Summary

The literature review has revealed that the ideas of CPS have been around since 2006 with various defining factors that make CPS a complex, wide-ranging next generation physical-aware engineered system able to integrate computing technologies (cyber part) into the physical world (Gunes et al., 2014). Lozano and Vijayan (2020) suggest that the goal of the CPS is to allow manufacturers to create flexible, high-efficiency and low-cost production achieved through physical and computational components working together to implement process in real time. Examples of CPS in action are seen within areas such as the capacity of sensors, actuators, devices, machines and robots to transfer data between them to create actionable operations which form the basis of smart industrial communities (Garetti et al., 2015). Wider application of CPS includes autonomous cars, connected logistics, problem-solving robotics, automatic guidance vehicles, automatic storage and a retrieval system.

The benefits of CPS may be significant in its purest form, but what may also be drawn from the literature are the challenges arguably associated with its adoption, from the ethical debate around widespread factory automation to the technical application discussions including security along with the costs of such systems.

Moreover, the diffusion of cyber physical systems is still ongoing, suggesting that many advantages and disadvantages are still unknown and yet to be uncovered.

Returning to the origins of Industry 4.0, Kagermann et al., (2013) predict that its impact will improve the flexibility and agility of the operation enabling one-off products to be manufactured at a profit. This flexibility within the operational system would then allow new business models to be created, leading to new ways to compete with low wage economies. The integration of these technologies would further assist in solving some of the challenges facing the world today, such as demographic changes, resource constraints and energy efficiency. These authors thus predict that the integration of the entire value network would allow for resource productivity and efficiency gains (Kagermann et al., 2013).

2.3 Assessing the Impact of Industry 4.0

2.3.1 Introduction

This section begins by providing an overview of the possibilities of Industry 4.0, starting with a global view then narrowing to a European study and finally to a UK-based study. The research begins by presenting evidence of how some actors within the global industry have adopted Industry 4.0, starting with a Chinese case study within the automotive sector followed by a survey of 92 Brazilian manufacturing companies.

An empirical investigation then follows into 59 businesses from the German-Danish border region regarding the implementation of Industry 4.0 technologies in the SME sector. The obstacles and challenges faced by German SME's regarding the adoption of the Industry 4.0 technologies are then discussed.

The final section then looks at the impact upon UK manufacturing by exploring the challenges and key benefits for small to medium-sized enterprises in the adoption of Industry 4.0 technologies within the UK manufacturing sector. Lastly, some ideas around the future of work will be discussed in a concluding section.

2.3.2 Adoption and Impact

Llopis-Albert, Rubio and Valero (2021) suggest that given the last 140 years of the automotive industry, the potential disruption caused by digital manufacturing is causing organisations to rethink traditional business models. Severe market competition, a new generation of electric vehicles, expansion efforts through globalisation, and consumer and product diversification are all driving factors causing the automotive industry to rethink traditional approaches to everyday business (Llopis-Albert et al., 2021). To confront these challenges facing the industry, the authors recommend that organisations adapt to these changes and to new trends in digital manufacturing. They suggest that the initial impact could transform into a beneficial business-to-consumer approach with the dealership network using data to engage in a partnership approach with customer and suppliers (Llopis-Albert et al., 2021, p. 2). Connectivity will lead to changes in business strategies, such as location-based servicing to sell products with a more value-focused customer experience.

Such digital developments will redefine the way in which manufacturers communicate within the retailers, while consumers will benefit from more fluid interactions when buying products and services (Llopis-Albert et al., 2021). The authors predict that intelligent diagnostics system will connect to smart components and allow a signal to be sent when the components need replacing or maintaining. The use of advanced data analytics would then allow for a more targeted customer offer leading to changes in existing business models, presenting a more lucrative opportunity for automotive manufacturers. This digitised and integrated approach to value chain management will increase the collaborated efforts of the retailer and manufacturer leading to increased efficiencies and cost reduction. They also suggest that by using sensor-driven technologies with vehicle-to-vehicle and vehicle-to-infrastructure integrated connectivity, improvements in increased traffic flow and safety will naturally occur (Llopis-Albert et al., 2021). Indeed, in many of today's automotive retail businesses, more collaborative ways of engaging with consumers are beginning to evolve. Recorded summary vehicle diagnostics, wear sensors, service notifications and the connected dealer network stand alongside online vehicle sales as being commonplace in today's automotive industry.

What is presented above (Llopis-Albert et al., 2021) arguably presents the potential of Industry 4.0 and its applications around connectivity across the full value chain. While the ideas are endless regarding the possibilities of Industry 4.0, the rest of the literature review and empirical investigation will seek to explore the reality.

A study by Lin et al., (2018) into the critical success factors for successful implementation of Industry 4.0 within the Chinese automotive industry begins by suggesting that analysis into how China has responded to Industry 4.0 is fraught with many challenges. They report a dearth of literature regarding the implementation of and impact of Industry 4.0 practices especially within China. They also suggest that with China being a developing country, the challenges associated with unbalanced resource distribution is an additional factor associated with their research challenges. The authors conclude that without a good level of understanding of Industry 4.0, China will be unlikely to develop the most appropriate strategy for Industry 4.0 execution (Lin et al., 2018, p. 590) and although the level of adoption is gaining momentum, it is still in its early stage. Here the authors use the (Tornatzky & Fleischer, 1990) technology, organisation and environmental (TOE) adoption framework as their research instrument and then present evidence which, in their opinion, supports their choice.

In turn, Lin et al., (2018) establish 6 hypotheses to test survey-based questionnaire, adapting them to a 5-point Likert scale. A significant 88.3% response rate has been achieved through a 31-question-based survey which was sent out to 37 automotive companies based within China (Lin et al., 2018, p. 597). The results of the survey confirm that in response to Industry 4.0:

- H1. Maturity of the IT has increased the use of advanced production technologies.
- H2. Technical incentives have increased the use of advanced production technologies.
- H3. The perceived benefits positively influence the use of advanced production technologies.

- H5. Environmental pressures positively affect the increased use of advanced production technologies.
- H6. Governmental pressure is confirmed positively in the increased use of advanced production technologies.

Lin et al., (2018) present interesting evidence supplied by various authors reporting that company size can be a factor which determines whether or not a company adopts the technologies. However, their research hypothesis 4 fails because company size and nature are not alone able to secure the increased use of advanced production technologies. As with much of the literature mentioned earlier, the impact of Industry 4.0 is still treated very conceptually and the approach of Lin et al., (2018) is no different. As mentioned already, what is conceptually presented, and the actual reality could be somewhat different. The authors also discuss the willingness and intention to adopt the advanced technologies but provide no evidence to suggest this has happened.

A further critical dimension to be added to the work of Lin et al., (2018) is the correlation between the sample and the demographic data. Their questionnaires were designed with automotive industry in mind, encompassing academics with the target population of senior managers and technical executives from with the Chinese automotive industry. The findings of Lin et al., (2018) thus suggest diversity in the level of knowledge where 45% have a basic understanding of the concepts and 34% have heard the ideas but with sparse understanding. Therefore, from within this case 79% of the respondents have a basic-to-low understanding of Industry 4.0.

Although the five of the six hypotheses confirmed reflect accurate judgement, the level of understanding of Industry 4.0 among the respondents was low (Lin et al., 2018), as has been outlined above. As a hypothesis then, the relationship between company size and the nature and adoption of these advanced technologies is insignificant. Again, due to the low understanding of Industry 4.0 and the level of complexity surrounding the integration and practical applications of the industrial technologies, can a credible judgment be made? This level of uncertainty within the target population provides difficulty in validating some of the afore-mentioned questions (hypothesis).

What can be drawn from this research is that the level of understanding is low and adoption is fraught with many challenges both internal and external to the organisation. Gillani et al., (2020) presents research from Zangiacomi et al., (2017) which supports this conclusion by outlining how the lack of understanding surrounding the complexities of implementing the technologies can lead to failed execution.

Frank et al., (2019) present a cross sectional survey of 143 manufacturing companies in Brazil machinery and equipment builders association regarding the implementation patterns of Industry 4.0 and associated technologies. The targets for the survey were the operations director and chief executives with 92 complete questionnaires equating to a 64.33% response rate. The background for the research was the emergence of a new industrial stage with its associated digital technologies with the intention of the study to address in particular the lack of understanding of how companies were to implement these technologies. The authors suggest that the complexities of the Industry 4.0 movement is a particular concern for companies when working out where to start their technological journey. Instead, the authors underline that Industry 4.0 combines two dimensions, the first of which consists of interconnected, intelligent communications known as the base technologies. The second dimension of the operational or front-end technologies then focuses upon smarter ways to operate within the business via smart manufacturing processes, products, supply chain and operating tools.

In this study, the initial analysis began by clustering the organisations into three main groups based upon the adoption profile. Cluster 1 was the low adopter group, cluster 2 were the moderate adopters and cluster 3 were the advanced adopters. The results of the survey report that the connection of smart manufacturing to smart products has a central role to play in Industry 4.0 (Frank et al., 2019, p. 18). One of the hypotheses tested during the research demonstrates a strong relationship with the adoption pattern of the smart manufacturing technologies and showed the maturity level of the organisation as oriented toward the goal of Industry 4.0. Here, vertical integration, traceability, energy management and their associated technologies demonstrated the highest levels of implementation followed by visualisation and automation. The least implemented technologies were additive manufacturing and flexible lines. These findings do corroborate with the researcher of this thesis proposition in that Industry 4.0 is about intelligent technology interconnectivity and aggregation.

For the second hypothesis, the authors confirmed that there was a connection between those organisations fitting into the advanced adoption cluster between the adoption of smart manufacturing technologies and smart product technologies. Their research then demonstrated that smart supply chain and smart working were still in the early stage of development, with only remote monitoring and collaborative robotics used within the advanced adoption cluster (Frank et al., 2019, p. 20). With regard to the adoption levels of these technologies, the internet of things, cloud, big data and analytics were then shown to be more prominent within those organisations in falling within the advanced adopter cluster.

While the research of Frank et al., (2019) is useful in several ways it does have some limitations. One of which is recognised by author's in as much as almost half of their chosen companies are from within the agriculture sector which is predominantly business to business (B-to-B). However, the researcher of this thesis suggests that a major weakness in this research is that Frank et al., (2019) fail to recognise the important of the human element is engaging in organisational change. The idea around the human element has two different facets, one of which is the acceptance of technological integration by the workforce and the other is around the leadership required to engage staff through the change process.

Drawing upon 17 years of experience working within the consultancy sector, the observation to be made by the researcher of this thesis is that there is much evidence of some people having a natural resistance to any form of change. Since Industry 4.0 concerns the integration of smart manufacturing, supply chains, working with products with intelligent decisions and communications of big data, analytics, cloud and the internet of things, this integration arguably removes decision-making power from workers to provides a more intelligent and autonomous factory. These technological developments may indeed incite fear in members of the workforce who may have the view that the evolving technologies will replace the blue-collar worker. This area will be covered in detail later within the literature review.

One other suggestion of weakness is the investment required to implement such an array of technologies which may also stop businesses from starting their journey to Industry 4.0. For large organisations, it is more likely that implementing these technologies could constitutes a significant investment while it may prove too much of a cost for small to medium-sized business. However there is still debate within this area as the cost of implementation may not be a significant factor.

The work of Frank et al., (2019) provides a highly useful guide in categorising the today's technologies and the Industry 4.0 technologies or base technologies, including the proposition that cyber physical systems should form a part of this grouping. Justification for the above will then be outlined within the conceptual framework section of this thesis. Hence the research of Frank et al., (2019) provides a grounding in making sense of the complexities surrounding the technologies associated with Industry 4.0. This research uncovered the advanced adopter of Industry 4.0 as indeed using the internet of things, big data, cloud and analytics which is a positive step towards implementation efforts of Industry 4.0.

Yu & Schweisfurth (2020) have also presented an empirical investigation into 59 businesses from the German-Danish border region regarding the implementation of the Industry 4.0 technologies in the SME sector. The authors note that despite the amount of research available in Industry 4.0, focus on the adoption of the technologies within the SME sector has been small. From the authors' very brief literature review, they report that previous research from (Alcácer & Cruz-Machado, 2019; Galati & Bigliardi, 2019; Liao et al., 2017; Mohamed, 2018; Theorin et al., 2017) finds that due to the ambiguous benefits, large investment, lack of knowledge and skills and unclear implementation process, industry has been hesitant to implement Industry 4.0 technologies, especially in SME's. Here the authors' empirical studies are focused upon determining the factors driving the implementation of Industry 4.0, dividing them into technological, company-related and industry-related factors (Yu & Schweisfurth, 2020, p. 79). Yu & Schweisfurth (2020) summarise their findings by identifying that the degree of technological relevance, knowledge and the impact on organisational flexibility are all technology-related factors. Along with strategy and readiness, the size of the company is the organisational factor and finally the regulatory, industry pressures and globalisation strategies are the industry-related factors driving the implementation of Industry 4.0 (Yu & Schweisfurth, 2020, p. 79).

The author's own investigation sampled 8.9% of 665 manufacturing SME's exclusively from the German-Danish border region and then set out to analyse the three factors, identified above: the degree of technology implementation; company diversity; and industry related factors (Yu & Schweisfurth, 2020 p. 79). From their findings regarding technology implementation, the authors determined that few of the organisation have implemented any Industry 4.0 technologies, and many have no plans to do so (Yu & Schweisfurth, 2020, p. 79). The technologies chosen are outlined on page 81 of this article and, interestingly, out of all the organisation reviewed many of them have limited interest in implementing big data and the internet of things while no organisation has any plans to implement augmented reality. Instead, 20% of the SME's have implemented cloud computing and system integration, while 50% of the companies have plans to implement cyber security within the coming years. As the authors have rightly highlighted, the technologies already implemented or which they are planning to implement are extensions to existing information systems and cannot be said to offer anything new (Yu & Schweisfurth, 2020).

The degree of implementation of these Industry 4.0 technologies within the authors Yu & Schweisfurth (2020) is then 'remarkably low' even though the phenomenon was established in Germany 9 years before this research was published. The Industry 4.0 adoption timeline within the sample is surprisingly low given that over 60% of the sample do not have any plans at all to implement big data, cloud computing and internet of things. To compare these findings to the base technology grouping suggested by Frank et al., (2019) which are arguably the technology grouping which makes Industry 4.0 a reality. One school of thought is that 60% of the organisations in this research have no plans at all to implement Industry 4.0.

Schröder (2016) has published a report on the obstacles and challenges faced by the German SME's 'Mittelstand' regarding the adoption of Industry 4.0 technologies. The rational for this research institute report is the recognition that although 25% of value creation in Germany is due to industry, the lack of engagement with the ‘Mittelstand’ companies is a cause for concern. Their report outlines that 95% of all companies in Germany are a part of the SME network while 690,000 of these companies are focused on production alone, but from this population, only 5% are ready or in a position to adopt Industry 4.0 principles (Schröder, 2016, p. 6). The author reports on 2015 findings, suggesting that around 25% of the SME’s researched have not looked at Industry 4.0 at all. What has been drawn from these findings is that the size of the business is a major factor in determining the level of Industry 4.0 adoption, the leading sectors here being rubber and plastics manufacturers along with machinery and plant engineering. The technicalities hindering adoption thus include the lack of digital strategy and resources which affects four out of ten SME’s, concerns regarding cyber security/storage and the lack of standards to ease implementation.

Evidence of this lack of digital strategy and high capital demands is also supported by the research of Llopis-Albert et al., (2020) in a study conducted within the Spanish automotive industry. Schröder (2016) also reports that SME’s have not yet discovered big data and the cloud, which are arguably the key enablers of Industry 4.0 (Schröder, 2016). Interestingly, Schröder (2016) reports that without the involvement of management, the implementation of Industry 4.0 and its associated technologies will be limited within the sector. In addition, this research also finds that SME often adopt standards set by the larger organisations they supply and because of these, the wider SME network will not join the value creation process thus providing limitations to the wider adoption of the technologies. Schröder (2016) then suggests that the adoption of Industry 4.0 will depend upon what he defines as ‘framework conditions’, which include legal framework conditions, high-performing brands, financing support, skilled worker availability and support from the state as factors which will be supported by this adoption.

While questions may be raised as to the validity of the report given, Schröder (2016) initial research was conducted in 2015. What can be taken from this research is that the overall engagement of the SME network on the path of Industry 4.0 is slow and has many challenges where only 5% of the overall sample are in a position to adopt Industry 4.0. The research suggests that adoption is not so straightforward, and several technicalities exist for the implementation. One such technicality is the lack of digital strategy which is also supported with the work of Llopis-Albert et al., (2020) and the research into the Spanish automotive sector. Digital strategy will be discussed during the conceptual development section.

Masood and Sonntag (2020) report that despite the emerging conceivable benefit of Industry 4.0 and its associated technologies, much of the focus has been on large enterprises despite the fact that small to medium-sized enterprises (SME) represent 90% of the registered companies within Europe. The authors present evidence which suggests that research into Industry 4.0 and the SME market has only recently gained momentum and the work that has been done so far presents little in the way of proposed solutions. Going by the literature review, the authors of this study present several challenges to the adoption of the Industry 4.0 principles (Masood & Sonntag, 2020, p. 3) within the SME sector, which has led to two gaps in the current literature. They are

'There is a disconnect between current I4.0 technologies and the characteristic needs of SME organisations'.

'There is no clear method to evaluate I4.0 technologies against the needs and requirements of specific SME organisations'.

(Masood & Sonntag, 2020, p. 3).

To address the research gap, the authors propose the six hypotheses outlined within the article. Masood and Sonntag (2020) thus present survey-based research exploring the challenges and key benefits for small to medium-sized enterprises in the adoption of the Industry 4.0 technologies within the UK manufacturing industry. This is closely aligned to the overall aim of this thesis. The target recipients were individuals who might influence the technology implementation process to include operations managers, executives and directors from within the SME network, evidence of which is in the main body of the article (Masood & Sonntag, 2020, p. 7). Of the 1061 opinion-based surveys distributed, 238 finished the survey entirely, while of the six hypotheses tested only three of them were accepted (Masood & Sonntag, 2020, p. 8).

This study thus concludes research that both company size and attitude toward Industry 4.0 have a positive impact in making the most of the benefits of implementation. Moreover, the authors report that the complexity of the manufacturing system also presents itself as positive in the face of the challenges and this is in alignment with the gaps within their current literature review. Masood and Sonntag's findings present a challenge-to-benefits 2x2 matrix (2020, p. 10) where 8 of what they describe as Industry 4.0 technologies offer greater benefit in relation to the challenge incurred.

The authors also present qualitative responses which suggest that the challenges for implementation include the finance, the complexity of Industry 4.0, questions of security and the 'inertia' to do with the scale of change. Interestingly when asked about preparing for Industry 4.0, the common themes coming from the qualitative response were training, support, time, awareness and investment (Masood & Sonntag, 2020, p. 7). Planning for Industry 4.0 is also discussed during the conceptual development along with the empirical investigation within this thesis. As training and support is needed, it can be suggested that what has been uncovered within their literature review has been confirmed within their research. Indeed, a gap in knowledge does exist within the UK SME sector.

Although the article provides an insight into the UK SME sector in the adoption of Industry 4.0, it may be suggested that there is conjecture within their findings. One such instance is the validity of the method of Masood & Sonntag (2020), where an opinion-based survey is asking question on benefits and challenges of Industry 4.0 adoption to respondents who have been confirmed to have a lack of knowledge. This idea is further confirmed within their complexity and benefit table as the respondents are suggesting high benefits of technologies which are nothing more than today's technologies, other than perhaps in the case of big data and analytics. Other conjecture includes the actual use of the technologies is to be disregarded from within the research (Masood & Sonntag, 2020, p. 4). If the respondents have not used the technologies, then advising on challenges and benefits arguably lacks validity.

What can be drawn from the work of Masood & Sonntag (2020) is that a knowledge gap does indeed exist within their reviewed literature along with what has been found within their questionnaire. The finding also suggest there has not been much in the way of Industry 4.0 impact.

2.3.3 Adoption and Impact – Summary

Fundamentally, what can be drawn from the literature is that the implementation of Industry 4.0 is only in its early stage and its current impact is limited. There are signs that here some actors are further along the diffusion curve than the findings show in the work of Frank et al., (2019), but in general the momentum is only beginning to occur.

Some of the challenges highlighted through this section include the lack of general knowledge, the complexities surrounding the technologies and where to start the deployment journey. The lack of people engagement and leadership, uncertainties around financial commitment needed, the lack of digital strategy and the reality of Industry 4.0 itself is on the operational agenda of some.

What can be drawn from a literature review is that many are suggesting Industry 4.0 is the next industrial revolution, but what has been presented from the literature seems different. After 10 years of Industry 4.0, the evidence suggests that this technological phenomenon is just starting to evolve.

2.3.4 Future of Employment

As with many evolving industrial phenomena, there seems to be an initial hype as to the potential of Industry 4.0 and conversely an equal level of scepticism. Arguably, it is a natural human reaction to be worried as to how these technologies will affect businesses and the people who work within them, and perhaps no more so than with the rise of industrial automation coming from the third industrial revolution in the 1970's. Within any modern automotive manufacturer, the level of automation is commonplace in terms of parts delivery with automatic guidance vehicles (AGV's). However, industrial automation is still evolving and the predictions about mass job losses coming with industrial automation has still not transpired.

While there is still much confusion within the literature about conceptualising Industry 4.0, one of the concepts coming to the fore is the increasing level of automation. Frey and Osborne (2013) predict that within the next two decades the potential implications of AI and automation will put 47% of American jobs at high risk. In this context, the risk falls on the jobs anticipated to be automated. Kusiak (2016) supports this prediction as he believes that the introduction of next-generation factory automation and low-cost robotics will introduce cyber employment rather than traditional jobs and facilitate the general shift from blue to white-collar jobs.

Frey and Osborne (2013) develop this prediction further and report that advancements in robotics, AI, sensor technologies and machine visions systems are tasks that only a few years ago were predominantly performed by humans. The authors suggest that due to further advancements in robotics, it is not only routine tasks but more sophisticated tasks that will be performed through robotics. Their analysis focuses on 702 occupations to examine the potential impact of computerisation; they then report in several papers on the different reasons why jobs are shifting towards computerisation, from routine jobs leading to low rates of employment to the shift away from manufacturing to service occupation to technological innovations disrupting labour markets making workers redundant. However, the authors do recognise that the notion of technological unemployment is nothing new and mention the Schumpeterian theory of creative disruption. Following on from these findings, they provide several instances throughout history when technological advancements have resulted in a shift away from low skills jobs to computerisation. They also present evidence suggesting that the service occupations which have seen the biggest growth in the last decade are also vulnerable to a shift in computerisation. The main occupations at risk thus include labour and production, transportation and logistics, office work and administration.

From one perspective it is possible to argue that what Frey & Osborne (2013) suggest about Josephs Schumpeter's (1883-1950) ideas on creating destruction within the context of Industry 4.0 is perhaps at this point somewhat misleading.

However, that is not to suggest the traditional way of manufacturing will not evolve through the implementation of such technologies. From an alternative perspective and a quite purist view of Industry 4.0, if all the barriers to implementation were to be removed then one could suggest their revolutionary potential. It may be suggested then that what Frey and Osborne (2013) report in identifying 47% of the US labour pool at risk is perhaps a frightening consequence of this radical potential.

Pereira and Romero (2017) suggest that Industry 4.0 has the potential to impact domains which are further out of reach than the industrial sector. They suggest six areas that might be affected by Industry 4.0: the working environment, business models, skills development, products and services, companies and markets. The authors hence offer a slightly different viewpoint from that of Frey & Osborne (2013) in stating that the future of work will need a skills shift, and where new skills, knowledge and competencies are needed for the acquisition of new knowledge within the factories of the future. Here the author also recognise that the impact of the labour market could be significant as the shift to more professional roles takes place.

Similar ideas have been suggested by Bonekamp and Sure (2015), who present findings from interviews with seven individuals representing scientific institutions, consulting and the industrial community. The research here was designed to get an expert opinion on the impact of Industry 4.0 on the labour pool within organisations. The authors' conclusions suggest a skills shift in line with the research of Pereira and Romero (2017). Bonekamp and Sure (2015) then discuss a decrease in low-skilled positions but an increase in highly skilled roles, interestingly suggesting that the prerequisite for this shift in skills is orientation towards further educational development and lifelong learning activity.

2.3.5 Future of Employment - Summary

From the more sceptical view of Frey & Osborne (2013) to a more perhaps pragmatic view suggested by Pereira & Romero (2017) and Bonekamp & Sure (2015), the ideas about Industry 4.0 and its impact upon job losses is open to much debate. Pereira & Romero (2017) and Bonekamp & Sure (2015) appear to be suggesting is the possibility of bringing a more realistic dimension to the discussions around the impact of Industry 4.0 and the future of employment. As workplace technology evolves so will the need to improve skills and knowledge, and here it might be argued that skills development or a skills shift is perhaps not a bad thing for industry and society in general.

On the other hand, Frey & Osborne (2013) and Kusiak (2016) have suggested the impact of Industry 4.0 will be mass job losses in the manufacturing sector. As Industry 4.0 evolves, so will the debate into job losses and reskilling. It can be suggested that a 'skills shift' will occur which will be needed to keep up with the changing technological demands. However mass job losses are still an unknown and will be explored further within the empirical work.

Chapter 3 - Conceptual Framework

3.1 Introduction

This chapter introduces the conceptual framework which will assist in bridging the gap between the literature and the empirical analysis. This conceptual framework has been used as a guide to determine which data to collect throughout the empirical investigation. The data presented below connects the literature review with the methods which assists the researcher is clarifying and defining the research questions.

The conceptual framework has taken on many iterations and has evolved during the course of the research. What is presented below builds upon the conceptual framework suggested by Frank et al., (2019) and aligns it with the research questions and the transformation process model which is often employed in studies of operations management such as Slack et al., (2019). This framework then aligns the research questions with the three main categories of the transformation process and further develops the ideas offered by Frank et al., (2019).

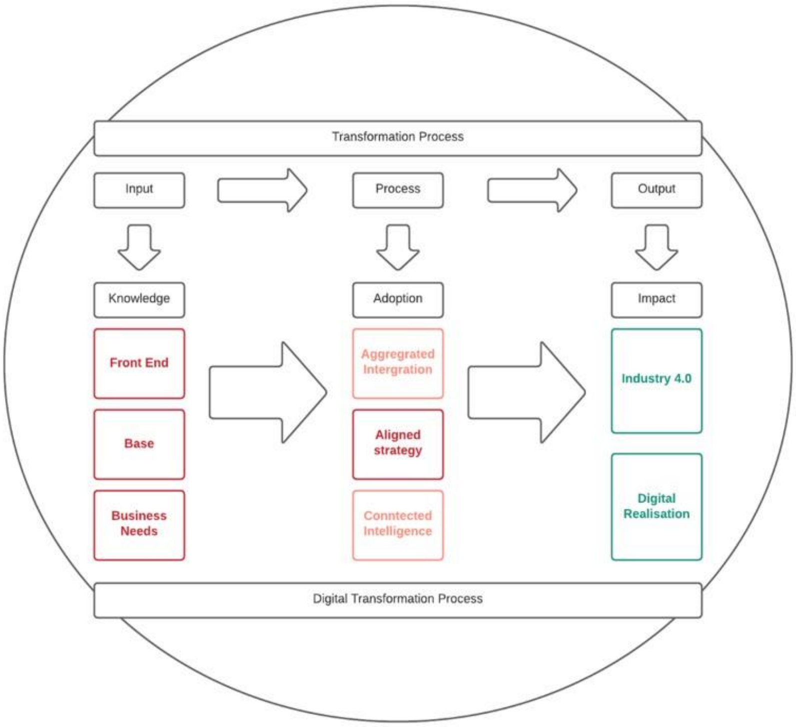
3.1.2 The Conceptual Framework - A General Overview

The concept of a transformation process can be used to describe the general nature of operations and has been used in the operations management literature such as in the research of Slack et al., (2010). In simple terms, it takes a set of resource inputs and transforms them into goods or service outputs directed towards satisfying the needs and demands of the customer. The model conforms to most operations and can generally be described as the input of man, material and machine, then transformed through the process into a product or service measured according to quality, cost and delivery (Slack et al., 2010). As with many conceptual models, there are several variations of the transformation process, but the basic input-process-output model will be used for this conceptual framework. The reason for its use is that the model proposes that a predetermined set of inputs of man, material and machine be transformed into an output that ensures the product or service is delivered at the right quality, cost and delivery to the customer.

The research questions of knowledge, adoption and impact are then overlayered onto the input - process - output (Slack et al., 2010) transformation process model. In this way the three pillars of knowledge, adoption and impact are built up to provide the key elements of the conceptual framework (see figure 4.0), which are then used as a guide to enable the researcher in what to explore within the empirical research. Hence the structure of the conceptual framework is based on the findings from the literature. The concept of the pillars then provides guidance for 'building the picture' of the level of knowledge, adoption and impact of Industry 4.0 from within the UK automotive manufacturing industry.

The input element at the base of the knowledge pillar indicates what to explore from a knowledge perspective by building upon the conceptual framework proposed by Frank et al., (2019). It also provides guidance as to what technology grouping to explore. Cyber physical systems are them added to this grouping again in line with the findings of the literature research. The conceptual framework (see figure 4.0) developed for this research study utilises a third conceptual 'building block' in additional to the two taken from Frank et al., (2019), so drawing upon the needs of a business to determine whether the business is strategically thinking about Industry 4.0 and is at all ready for change (Yu & Schweisfurth, 2020, p. 79).

Figure 4.0: The Conceptual Framework



Source: Author

Appendix 1.0 outlines all the technologies associated with the front-end and base technologies, as suggested by Frank et al., (2019) and further developed by the researcher of this thesis.

The process of adoption provides guidance as to what to explore within the research. From an adoption perspective, the three 'building blocks' of this pillar suggest technology aggregation, intelligent connectivity should be explored in terms of their alignment to a business strategy or 'need' . Finally, the output or impact pillar provides further guidance by suggesting that the impact of Industry 4.0 can only be confirmed if a selection of the base technologies (Frank et al., 2019) are aggregated, connected intelligently with today', front-end technologies (Frank et al., 2019) and then aligned to a business need. These findings can be used to explore difference between todays evolving technologies and that of Industry 4.0 from within the research.

3.1.3 The Knowledge Pillar

The knowledge pillar (see figure 4.0) brings together the front-end technologies and base technologies presented by Frank et al., (2019), along with an additional element which is perhaps prerequisite to successful adoption: the business need.

As discussed earlier in the literature review, the front-end technologies presented by Frank et al., (2019) segregate the technologies into Smart manufacturing, products, working and supply chain. Smart manufacturing categorises six main groupings consisting of vertical integration, visualisation, automation, traceability, flexibility and energy management (Frank et al., 2019, p. 5). The smart product technologies comprise of connectivity, monitoring, control, optimisation and autonomy. Smart working utilises collaborative robotics, augmented reality, virtual training augmented reality for maintenance, remote monitoring and operating. Finally, the Smart supply chain utilises digital platforms with customers, other business units and suppliers (Frank et al., 2019, p. 8). The base technologies are broken down into four main technologies which are the internet of things, cloud computing, big data and analytics. It is also recommended that cyber physical systems be added to this grouping, as outlined within the technology section of the thesis.

The business-needs block evolved from what has been uncovered from within the literature review and the ideas technology and strategic intent. The researcher needed to explore if industry were pushing technology for the sake of pushing technology or was it being used by industry as a strategic enabler for productivity / business excellence. Within this context business need refers to the exploration to determine if Industry 4.0 was at the forefront of strategic decisions made by business leaders. One way to determine this is to explore empirically if the organisation is ready for change. Here the literature review reveals inconsistencies and various models of readiness (Hizam-Hanafiah et al., 2020) in how organisations are planning for Industry 4.0 and the organisational change which will come with it (Yu & Schweisfurth, 2020). The organisational readiness discussed within the literature review suggests an organisation should be ready for change through specifically understanding the needs of the business (Lichtblau et al., 2015). The additional requirement to clarify the business needs suggests that the organisation and its leaders need to understand what the specific objectives of the overall digital transformation are. This concept can provide clarity of purpose along with avoiding technology push and technology for the sake of it. The researcher proposes a vision or strategy for Industry 4.0, to understand the voice of the customer, the transformation of the operational value stream and finally a people engagement strategy should be included within the conceptual framework.

The section dealing with the transformation of the value stream will allow the researcher to determine which part of the business has Industry 4.0 been implemented. This will provide further clarification of the extent of implementation efforts.

The final element in the knowledge pillar outlined within the business needs section is the concept of digital engagement. The concept here is to understand how the respondents and interviewees engage with staff on the journey to transformation. Research here will hence focus upon if there are a shift in skills, and if mass job losses are underway like many are predicting (Frey & Osborne, 2013; Kusiak, 2018; Pereira & Romero, 2017; Schröder, 2016). In essence, this provides the researcher with clarification of which data to collect.

3.1.4 The Adoption Pillar

When considering the context of adoption, it is necessary for research to explore how aggregation, integration and intelligent connectivity are strategically aligned to a business need. The conceptual frameworks bring together these ideas and allows a redefinition of what to explore. It is therefore not stand-alone, isolated technologies which makes Industry 4.0, but the aggregated and integrated technologies which have a strategic purpose for the business.

These technologies should then be aligned to the right business strategy connected end-to-end within the business. Here Frank et al., (2019) suggest that operational end-to-end technologies are more aligned with the front-end technology grouping. Connected intelligent systems then require integration of the base technologies of the internet of things, cloud computing, big data analytics and cyber physical systems to create an industrial ecosystem uniquely designed for each individual business providing connected intelligence linked from the customer through operations and then onto the supply chain. This intelligent aggregated connectivity serves to connect the front-end technologies selected to be specific to the needs of the business. The work of Frank et al., (2019) has allowed a redefinition of the question not only from the perspective of technology classification but also from an interconnectivity perspective. Overlaying Frank et al., (2019) with the transformation process suggested in the work of Slack et al. (2019) then adds further clarity to defining what to explore in terms of data collection.

The question arises again here of whether or not the revolutionary aspect of Industry 4.0 can be concretely achieved. We can envisage this in terms of the capacity for aggregation and integration with either existing or new technologies, then connecting them via the intelligently executed systems of base technologies. The argument can thus be made that the aggregation and integration of connected technologies may lead to the great transformation of the operational workplace. In theory then, aligning business strategy to the customer's needs in a fully integrated approach could ensure the transition of the company to digital realisation and impact in a more measured way.

With regard to the adoption pillar, the question is not only of what technologies are in place but where these technologies are interconnected, strategically aligned and how they use data and analytics intelligence in their operational technologies. Without this aggregated interconnectivity, it is questionable whether they can be classified as anything other than existing or evolving technologies. Refining the adoption process through the conceptual framework has allowed a redefinition in what data to explore.

3.1.5 The Impact Pillar

As with the other pillars, the impact pillar can be treated as a multi-faceted concept bringing clarity to the definition of Industry 4.0 while also highlighting the difference between any technology impact and that of Industry 4.0. Building upon the clarity gained in the previous two pillars as regards impact, here the empirical exploration will seek to understand if impact is realised through aggregated, integrated and intelligently connected technologies. Any other technological developments should be referred to as little more than evolving industrial technologies. These findings again provides the researcher with clarity of what to explore from a data perspective.

The idea of digital realisation is built upon consideration of business needs and aligned strategic building blocks as this will allow further clarification of ideas around technology push or a strategic view of Industry 4.0. Arguably then, impact can only be achieved if there is a business need which is strategically aligned, meaning that it is measured and data-driven and so capable of digital realisation. This conclusion should provide further clarification into if Industry 4.0 has impacted the host organisations and if so how.

The failure to align digital efforts strategically will instead lead to isolated, ad hoc digital improvements with little in the way of measured impact. Digital realisation hence requires that a need within the business has been revealed, which could be the introduction of a new product or service, addressing a strategic concern within the business, or a strategic move on the part of the company to implement Industry 4.0. All such intentions have then to be aligned to a plan of implementation which outlines key milestones, measurables and performance indicators. These predetermined measures and strategy are to be realised by technological aggregation and connection; it is only then that digital realisation and impact can be validated.

This alignment of the impact of Industry 4.0 with the ‘output’ of the transformation process used by Slack et al., (2019) suggests that the outcomes are almost identical. The implication here is that the transformation model (Slack et al., 2019) suggests that through such transformation the outcomes are quality, cost and delivery are achieved. In turn, the outcomes of Industry 4.0 or digital transformation constitute the same key performance indicators of quality, cost, and delivery, the difference being with Industry 4.0 will be determine how much these key performance indicators have improved. These findings again provide guidance into what to explore during the empirical work which forms the basis of how to structure the questions and what data to look for.

3.1.6 In Summary

Bringing the operational transformation process model (Slack et al., 2019) together with that of Frank et al., (2019), not only provides insight into several of the facets and complexities of Industry 4.0 but for the purpose of refining the ideas about data within the empirical analysis. What has been presented within the conceptual framework outlined above, which provides guidance and clarification in how to operationalise the research. From a knowledge perspective, the focus will include understanding the general level of awareness of Industry 4.0 followed by a deeper exploration into the level of general understanding and the technologies presented by Frank et al., (2019).

The discussion of adoption here led to the conclusion that it is not the individual technologies, but the selected aggregated, interconnected and intelligently connected technologies that are aligned to the business needs defines Industry 4.0. It is only when these technologies are aggregated and interconnected that validation becomes possible of how Industry 4.0 has indeed impacted upon a business, and so confirming which data to seek through the investigation. These observations and analysis have hence provided further clarification of the difference between today's existing evolving technologies and that of Industry 4.0.

The impact pillar provides clarification of what data to collect when exploring the impact of Industry 4.0 by aligning the transformation process (Fig 4) 'output' as suggested by Slack et al., (2019). These findings again provides guidance and refinement in the research questions. Alongside understanding business needs, knowledge of front-end and base technologies are also presented as inputs to the process (Fig 4). Digital transformation occurs when the selected technologies are aggregated and integrated, with both being intelligently connected and aligned to the needs of the business which is explored through the adoption pillar. The aggregation of both pillars of Industry 4.0 implementation can then be validated or realised through the key performance indicators quality, cost and delivery drawn from the work of Slack et al., (2019).

Chapter 4 - Research Methods

4.1 Introduction

The following chapter discusses the chosen methods used to conduct the research. This explanation of the research methodology refers to the ‘research onion’ described by Saunders et al., (2016), using the onion metaphor to navigate through its methodologies and its intricacies. Given what the overall research has sought to achieve, this metaphor allowed the research to ‘take aim’ at the most appropriate methodology. The strategy was first to provide a broad philosophical perspective before reducing it through the methodologies discussed. Within the context of this study, the first step in ‘taking aim’ at the subject matter was then to confirm the research questions listed below.

A broad overview of the various research philosophies available is first given here to outline the balance of contradictory forces for each then justify the overall choice. Given the research questions, the second layer of the research approach involved a discussion and justification of the most suitable choice of method. The strategic choices for the research methodology have been discussed in a subsequent section, including a discussion of why a two-phase strategy has yielded better results than other options. A discussion about research design has also been included within this strategy section, while the final section outlines the time horizons and data collection methods selected.

4.2 Research Questions

The justification of the research methods chosen required an understanding of the most appropriate solution available for answering the research questions with rigour and depth. Initially, the research questions themselves needed to be evaluated. As highlighted earlier in this study, the research questions focused specifically on three areas:

> ***RQ1: What is understood by the term Industry 4.0?***

RQ2: To what extent are UK firms adopting Industry 4.0?

RQ3: What is the level of impact of Industry 4.0?

As evidenced from the literature, there seemed not only to be a level of confusion regarding Industry 4.0 but also a lack of agreed definition of this evolving phenomenon. The research provided by (Frank et al., 2019) did begin to make sense of the complexities, but what can mostly be drawn from this literature review is that the level of understanding was somewhat confused at this point. Hence, to explore this empirical research question, *RQ1* was designed to determine the level of knowledge and understanding of Industry 4.0 within a target population of the UK manufacturing sector.

Understanding how these firms have engaged with the technologies and ascertaining what the level of engagement is within each company would be key factors for answering the second question within the research. Here the factors to determine included the following: which of the technologies had been used; why, how and where in the value stream were the technologies to be introduced; and what did the company want to achieve through the introduction of these technologies into the business. The final question was designed to understand the level of success or impact that these technologies would have on the host business and its workers. Answering these questions would thus assist in determining whether or not their impact was transforming companies into organisations ready for a digital future.

4.3 Research Philosophy

This section provides a broad introduction to the different schools of research philosophy, highlighting the positive aspects of the different schools of thought along with an outline of why the chosen philosophy was either accepted or rejected for this thesis.

4.3.1 Positivism

Coined by Auguste Comte (1798-1857) in the nineteenth century, ‘positivism’ refers to the power of rational thought and science with a view to understanding and manipulating the world. As a philosophy it only referred to the tangible, rejecting metaphysical and subjective ideas (Fisher, 2010, p. 19) in an attempt to ascertain the objective truth (Whysall, 2015). The work of Bryman and Bell (2011) supports this notion in their suggestion that positivism entails five core principles pertaining to a scientific approach towards testing hypotheses (Bryman and Bell, 2011, p. 15).

Many advantages arise from a positivist approach to research, entailing a search for the truth through a consideration of scientific facts, their justification and validation. For many years the researcher’s professional background involved making sense of organisational efforts to push the lean agenda through data, information and validation. However, in the context of Industry 4.0, the complexities surrounding the research questions are perhaps more difficult to appreciate. If, as Bryman and Bell (2011) suggest, positivism is where “*knowledge is arrived at through gathering facts that provide the basis for laws”* then perhaps positivism is not the most suitable philosophy for dealing with Industry 4.0 as an emerging phenomenon.

The reality is that the evolving nature of this industrial movement can make the search for facts difficult. A survey of the research literature suggested that there is still much confusion around the ideals of Industry 4.0. Moreover, preliminary efforts on the part of the researcher to determine the level of impact were also inconclusive, while the rate of diffusion of the technology has proven difficult to determine. The researcher would then suggest that positivism alone provides too rigid an approach for achieving the best results for this thesis.

4.3.2 Realism

A realist philosophy arguably sits between positivism and interpretivism (Bryman, 2011), based as it is upon the belief that reality is independent of human thoughts and beliefs (Saunders, 2016). A realist believes that social reality can be modelled on empirically testing hypotheses (Fisher, 2010). Realist theory can then be divided into two groups: direct realism and critical realism. Direct realism views the world through a human prism and can be summarised as ‘what you see is what you get’. On the other hand, critical realism argues that humans do experience beliefs and viewpoints of their world that may alter the reality of the real world (Dudovskiy, 2016). Realism suggests that our representation of reality is how things really are. Any preconceived idea or opinions can then be removed as reality is based upon fact.

Although in the context of this research realism has advantages as a philosophy, it suffers from clear limitations in yielding the conclusions required. Instead, the emerging nature of Industry 4.0 calls for a mixed method approach to achieve the best results given the research questions. It may then be argued that realism does not provide the practical approach required for a research study of this nature.

4.3.3 Interpretivism

Often cited as an alternative to positivism, interpretivism is a subjective philosophy used to explore how people make sense of the world and the structure and processes within it (Fisher, 2010). This philosophical stance takes the variables and complexities of understanding the social world into consideration, as well as thinking about the possible ramifications as to why people reside in this world. Bryman and Bell (2011) suggest that social scientists should grasp the subjective meaning of social action since this philosophy is more about differences in social interaction, entailing that a better understanding of the qualitative methodology is generally preferred within this field of research.

Interpretivist research seeks to interpret social worlds and their contexts to gain a deeper understanding of what is meaningful to the research participants. Within the business context, this means seeking the perspectives of different groups of people within an organisation (Saunders, 2016). Interpretivism has different strands where, for instance, phenomenologists study the lived experience of the research participants. The study of organisational texts, images stories and symbols is then covered within the hermeneutics strand, while symbolic interactionists interpret the interactions between people through team working, social interaction, conversation meeting and direct observation (Saunders, 2016)

Given the richness of the engagement facilitated by this research philosophy, it initially appeared the most suitable choice given the research themes and the original strategy pursued by the case study design. However, given the changes of the interview strategy and survey, the decision was made to move away from interpretivism and embrace pragmatism, whose benefits as a philosophy can be significant within a certain organisational context. Nonetheless, engaging with different groups within the business in order to understand their experiences, participation and stories on Industry 4.0 might also have yielded good results.

4.3.4 Pragmatism

Delanty and Strydom (2003) identify the American philosopher Charles Sanders Peirce (1839-1914) as the founder of pragmatism, followed by William James (1842-1910) and John Dewey (1859-1952) as its principal figures. Pragmatism argues that the most important element in understanding which research philosophy is the research question itself (Thorpe, 2012). Pragmatism aims to find practical solutions able to inform research by starting with the problem and then choosing the most appropriate methods to solve the problem. The pragmatist interest is therefore in practical outcomes rather than abstract distinctions (Saunders, 2016).

Pragmatism argues that there are different ways to interpret the world and that what matters to the pragmatist is ‘reality’. In contrast, a more ‘naturalist’ approach would seek to understand the underlying complexities of the research question (Saunders, 2016). Instead, pragmatism proposes that social studies can be interpreted in myriad ways where no single position provides the entire picture (Dudovskiy, 2016), arguably paving the way for more practical and humanistic applications for this research philosophy.

Within the context of this research project, a pragmatic approach provided the researcher with several advantages. Firstly, the notion that there is no preconceived position provides a level of flexibility overall when selecting the methods required to navigate around an emerging phenomenon such as Industry 4.0. With the research questions at the forefront of pragmatist research, a flexible qualitative and semi-quantitative approach would appear well-placed to uncover the research questions. This flexibility provided the researcher with a more practical and engaged philosophical stance without the limiting factors associated with other stances, such as a purely positivist approach.

The researcher's decision to adopt a mixed approach hence provided an opportunity to gather a broader evidence base in support of more comprehensive analysis into the complexities of the research question within its emerging context. It is the opinion of the researcher that to have a preconceived stance about such an unknown, unclear and emerging phenomenon such as Industry 4.0 would have led to limitations to this research. Tashakkori and Teddlie (1998), for one, believe that a pragmatist approach seeks to study what is valuable to the researcher as opposed to engaging in pointless debates about concepts (Saunders, 2016).

4.3.5 Research Philosophy in Summary

Understanding the different ways in which we see the world is the key to selecting the correct research philosophy (Saunders, 2016). The way in which we see the world can ultimately determine the choice of path through research. As (Bryman and Bell, 2011) suggest, a positive approach to acquiring knowledge by gathering facts is clearly a very useful strategy within certain research contexts. However, the search for facts may lead to cases where there is a correct or incorrect answer. In the context of this thesis, the first conclusion drawn from the literature is that Industry 4.0 means different things to different people. Different definitions of the concept are suggested, but the study has been unable to determine one recognised and agreed-upon definition of Industry 4.0. Without supplying this basic premise in the definition of this technological movement, the search for facts is perhaps not as straightforward as would first appear. Moreover, in terms of the target audience of the research, this study will not assume that Industry 4.0 has been implemented within the organisations it has focused upon, entailing that further evidence and discussion will be needed to respond to the research questions. For example, if the research does uncover that the technologies have been implemented, then the researcher will seek to determine a tangible impact.

Again, the richness of the interpretivist approach offers very clear advantages in certain research contexts. Within the context of this study, for instance, clear benefits exist for engaging with people when the task is to understand the relevant aspects of the three research questions. However, as a philosophical stance interpretivism does have limitations within the context of this research in addressing aspects of the research questions, being that the researcher will need to determine the most tangible impact of the technologies being implemented.

As a research philosophy, pragmatism provides a flexible, unbiased approach enabling the researcher to focus upon the most appropriate solutions to answer the research questions. The options for validating this research from a qualitative and quantitative perspective removes any philosophical assumptions that the researcher may have and puts the questions at the heart of the research. Understanding the reality of Industry 4.0 from a variety of perspectives hence supplies research with a certain richness, leading to the decision to select pragmatism as the philosophy for this thesis.

4.4 Research Approaches

The following section provides an overview of the deductive and inductive research approaches. In doing so, it will outline the advantages and disadvantages of each approach given the context of this research.

4.4.1 Deduction and Induction

In aligning itself more to positivist philosophy, deductive theory is a structured scientific approach which uses theory to test hypotheses generally, although not exclusively through quantitative methods; in this sense, it can be described as providing a more top-down approach (Trochim, 2008). The deductive approach is to identify the relationship between variables with a view to determining causality and proof through the consideration of facts (Saunders et al., 2016). It is arguable then that deduction provides a robust approach when the aim of the research is to test a hypothesis - for example, within physics or chemistry.

However, as highlighted within the positivism section, on its own this approach provides too rigid a structure for this research. The emerging nature of Industry 4.0 and the lack of clarity about its nature entails an inability at this point in the research to determine whether or not the impact of this industrial movement can be validated. These drawbacks have hence provided justification for discounting this approach as being unsuitable in isolation for engaging adequately with the research questions.

The counterargument for opting for the inductive rather than the deductive approach is that the inductive approach can be described as a bottom-up approach, where observations and data gathering are used to build a theory (Maylor, Harvey, Blackmon, & Huemann, 2016a, p. 111). Maylor, Harvey, Blackmon & Huemann (2016) also suggested that inductive data can be analysed to identify patterns. As a more subjective approach to understanding meaning, inductive approaches are more qualitative in nature while the types of analysis employed have a more narrative and comparative nature, being that the researcher is engaged with the social world under examination (Whysall, 2015). Saunders et al., (2007) suggest that induction is about constructing theories by making sense of the data collected as part of the ongoing qualitative research. Arguably, this approach to building theory from the data collected does align somewhat with a grounded philosophy. It is hence reasonable to conclude that the exclusive use of a deductive approach within this research provides too narrow an approach to answering the research questions.

4.4.2 Research Approach in Summary

The discussion given above affirms that a deductive approach to testing and validating hypotheses is one that seeks to confirm whether some of the objects of this research do or do not exist. However, this study does not call for data collection and scrutiny on that objective level, which would constitute a rigid approach too structured and inflexible for the research purposes.

Certainly, deductive theory provides a more commonplace way to understand the relationship between theory and research (Bryman, 2011), perhaps providing a stronger argument for its adoption for this research than an inductive approach (Fisher, 2010). Thus, given its flexibility and flexible approach to data collection, an inductive approach has been selected for this research where social engagement and observations are both required for the study context. In support of this approach is the work of Dudovskiy (2016), who has described the use of inductive reasoning as the researcher using observations to describe a picture or construct abstractions to understand the phenomenon being studied through a bottom-up approach to knowledge.

4.5 Research Strategies

The process of selecting an appropriate research strategy began with understanding what the study was attempting to achieve and why it was trying to achieve it (Fisher, 2007). Within the context of this research, the evolving nature of Industry 4.0 made this activity challenging. As previously highlighted by this research, ‘Industry 4.0’ is primarily seen as a label, being first used in 2011 by the government of Germany while German national research institutes described an evolving transition and integration of digital technologies into manufacturing. Despite the research of (Kamble et al., 2020) and the supporting evidence recognising that since 2013 the number of publications surrounding Industry 4.0 has almost doubled every year, much confusion has surrounded this phenomenon. From the perspective of a researcher then, relatively recent developments in this evolving phenomenon have arguably provided the right level of complexity to decide the right strategy to use yielding the best results from the research questions. Having highlighted this point within the philosophy section, it should be asserted again that it was the nature of the research questions which determined the most appropriate overall approach to use. Here, the most appropriate strategy identified was a mixed approach, utilising a dual strategy of questionnaire surveys and exploratory interviews.

Certainly, the research strategy has changed several times over the life of this DBA. The original lean innovation research set out to use the action research methodology as a strategic choice, being that the focus was upon engaging an organisation and its staff on a journey of engaged problem-solving. As the main focus of the research changed, a later evolution of the research strategy placed the focus more upon the survey and case study. However, due to Covid-19 and the ongoing access restrictions, the final decision was made to focus upon surveys and interviews by way of a research strategy.

The next section provides a brief overview of the other relevant research strategies which might have been used within this research. The final section then provides justification as to why a survey-based interview research has been used, while outlining the approach taken to establish the study content.

4.5.1 Action Research

The German-American psychologist Kurt Lewin (1946) is generally agreed to be the pioneer of action research. He argued that research into social practices should be concerned with the study of general laws and the 'diagnosis' of a specific situation. This notion of social practice referred to the application of research based on teamwork, so diagnosing the best means of understanding and analysing which research methods work and which do not work. Reason and Bradbury (2008) then developed the notion further to define action research as *"participatory, democratic process concerned with developing practical knowing in the pursuit of worthwhile human purposes, grounded in a participatory world view"* (Coghlan, 2014). Further discussions by Coghlan & Brannick (2014) then explained that action research is *"research in action rather than research about* *action"* and that research strategy here is founded upon the notion that organisations can be understood through deliberate change. This deliberate change involved the collaboration, involvement, sharing of knowledge and complete engagement of the employees within the organisation (Pasmore & Friedlander, 1982). The upshot is that the process of action research involves a reciprocal process of experimentation by first understanding, evaluating and implementing changes then studying the consequences of these changes (Fisher & Buglear, 2010, p. 24)

While there are clear advantages to action research exist, as a methodology it did not fit the changed remit of this research project and could no longer be said the most appropriate instrument to achieve the detail required within the research questions. As the research questions here have sought to determine as a strategy the level of knowledge, adoption and impact of Industry 4.0, if any, then action research would have come too early in the adoption life cycle to be effective as the strategy selected. Due to the evolving nature of the phenomenon then, the researcher cannot assume that any UK-based manufacturing organisations have implemented Industry 4.0 technologies.

4.5.2 Ethnography

Ethnographic research is more aligned to the interpretivist schools of philosophy insofar because ethnography deals with the study of people and cultures in their own natural environment through a process of intensive field work (Maylor, Harvey, Blackmon, & Huemann, 2016b; Singer, 2009). Ethnographic research is therefore the study of cultures (Fisher & Buglear, 2010) or, as Saunders et al., (2007) suggest, a written account of people or ethnic groups. Moreover, ethnographic research requires the researcher to become a part of the social situation entailing that the research itself is more aligned to an inductive approach (Lee, N. & Lings, 2008, p. 62).

As with every research strategy, ethnography can provide a rich and diverse source of data by facilitating the appreciation of contextual behaviour within groups and subgroups. It addresses the rationale behind people's particular action and the drivers of their particular behaviour, which then facilitates a more detailed understanding of the organisational culture. The study of people and culture could be a useful strategy for this study when seeking to determine whether or not the industrial movement has been accepted by the people within the organisations in focus here. However, at this point in the research it is too early to determine whether or not organisations are even planning implementation or have started their technological journey to a digital future. Since the impact of the implementation of these technologies will be on technologically adept people, then it may be too early to determine belief systems and their value with any great accuracy. Therefore, ethnographic research was not selected as a strategy for this research.

4.5.3 Grounded Theory

As a strategy, the emergence of the grounded theory of qualitative research had a somewhat dark beginning with research into death and the dying in hospitals within the United States conducted by Glaser and Strauss in and around 1967 (Charmaz, 2014). Grounded theory is an approach where the theory generated from data collection and analytics provides a theoretical explanation of social interaction. Glaser and Straus (1967) proposed qualitative analysis as an approach that has its own logic and can generate further theories. Their intention was to construct theoretical explanations of social processes with the aim of shifting the descriptive nature of qualitative enquiry to that of explanatory theoretical frameworks, so providing a conceptual understanding of the phenomena studied (Charmaz, 2014). Their claim that theory emerges from data emerged in four founding texts: *Awareness of Dying* (1965), *The Discovery of Grounded Theory* (1967), *Time for Dying* (1968) and *Status Passage* (1971) (Bryant, Charmaz and Bryant, 2007). The emergence of a published book of grounded theory in 1967 suggested that the aim was to generate theory grounded in the data drawn from the accounts given by social actors (Saunders et al., 2007).

El Hussein et al., (1990) present the research of Strauss & Corbin (1990) as a proposition for a grounding of research in inductive logic, as grounded theory research has no preconceived hypothesis or theory to test. Here the researcher begins by collecting and analysing data and then generates a theory on this basis (El Hussein et al., 2014). It is arguable then that grounded theory and pragmatist philosophy are to some extent aligned. Within the context of this research they may be suitable for responding to elements of the research questions, but the final choice of the researcher was not to use grounded theory as the strategy most suited to addressing the research questions.

Justification of the selection of a strategy for this study hence lay not just in the need for a mixed method approach because it had more to do with the practical approach to grounded theory itself. Arguably, some of the richness of grounded theory lies in the detail provided by the interviews along with the quantity of interview data. At this point in the research, it was impossible to determine how many of the planned interviewees understood what Industry 4.0 is about or knew whether or not their host organisation has engaged with this industrial phenomenon. The data provided by the interviewees and their experiences could be very limited and perhaps fell short of yielding the results required alone, meaning that yielding the best results in the questions answered entailing approaching the research from different perspectives. In terms of selecting methodology then, grounded theory might not have been the best option for answering the research questions.

4.5.4 Case Study

A case study may be defined as *“research that involves the empirical investigation of a particular contemporary phenomenon within its real-life context”* (Saunders, 2016, p. 473). For Yin (2014), case study research arises where there is a need to understand complex social phenomenon and explore “how” or “why” this phenomenon works (Yin, 2016, p. 4). Case studies are generally qualitative although both quantitative and qualitative methods can be used. The flexibility and depth of this comprehensive approach to research make a case study strategy a strong one for understanding complex phenomenon, whether the case is a system or policy, an institution, programme or a person (Simons, 2009).

A case study is an empirical enquiry which investigates contemporary phenomenon within its real work context (Yin, 2013). Given the contextual factors then, this study into how companies (in the ‘real world context’) are adopting the principles of i4.0 (as a ‘contemporary phenomenon’) provides initial justification for the correct selection of this strategy. Moreover, a typical case enquiry will include many distinct variable situations within the organisation being studied, so leading to multiple sources of evidence-gathering, triangulation and detailed analysis (Yin, 2013). As this research will span different organisations within different sectors, the flexibility provided by a case study strategy provides the opportunity to gain data and evidence through multiple sources within different manufacturing contexts allowing for richness within data collection.

As previously highlighted, however, due to the Covid-19 pandemic much of the access to the companies initially highlighted for the research was unfortunately withdrawn. Through initial dialogue, it was then confirmed that this withdrawal included three of the existing clients of the researcher who had given preliminary permission for the research to take place and one manufacturer run by a colleague of the researcher. Those leaving the project were an American OEM, a Japanese Tier automotive company, a British flow controls manufacturer and an American Tier 1 automotive company.

4.6 The Research Strategy Selected

The original strategy designed to address the research questions outlined a two-phase approach which first utilised a survey-based strategy followed by a smaller number of case studies. Due to the ongoing Covid-19 restrictions, it was then decided that interviews should be used to yield the best results. The justification into why a two-phased approach was used is due to the evolving nature and the lack of a clear definition of Industry 4.0, which arguably did not provide a basis from where to start. The original thoughts of the researcher was that a quantitative approach in isolation has limitations, while the exploratory nature of interviews would support the hypothesis that the foremost drive of this study is to answer the research questions.

4.6.1 Survey-based Research

The general purpose of a survey is to obtain statistical information from a sample population through the collection of quantitative or numerical data (Fowler, 2014). Sapsford (2007) describes a survey as a population and is counted as such while also describing what is out there. This quantitative approach does offer some significant advantages when the research questions are seeking a reliable way of determining validation and quantification. Unlike other quantitative methods, survey-based research can be used as a strategy to engage with a social entity by make a sample of leaders or people of influence within the host organisations. However, the nature of how surveys are structured can lead to a more closed approach to questioning which, considering the context of this research, does have its share of limitations and explains why a two-phase approach was thought to be more suitable for this research.

Sapsford (2006) sets out five questions that need to be answered when analysing the appropriateness of a survey-based research strategy:

1. *Is the research feasible at all in these circumstances?*
2. *Is survey research the right way to accomplish the problem, to get the kind of answers that are required?*
3. *Is a survey feasible here – would it yield the valid conclusions?*
4. *Is it ethically appropriate to use survey method here rather than some other approach?*
5. *Is it ethically and politically appropriate to carry out any form of research, given the research questions and social context?*

(Sapsford, 2006)

In terms of the target population, the planned sample for the questionnaire survey was to include regional and national automotive bodies, an automotive research centre and national trade bodies. The researcher’s own network was also used both through personal communication and through LinkedIn.

4.6.2 Questionnaire Design

After numerous further iterations of the questionnaire made with the supervisory team in January 2021, an initial pilot survey was sent to ten business associates from an automotive background or working within academia. The purpose of the survey was to determine whether or not the respondents from the automotive sector could make sense of the terminology used and understand the structure of the questions and what was being asked within the content. One additional consideration was how to determine the useability of the interface of the JISC software platform and the routing of the questions.

The questionnaire was issued to several academics, one of whom was a professor and a DBA graduate long with a DBA researcher. The rationale for the research here was to gauge their initial thoughts on structure, focus and outcome from three different viewpoints. Unfortunately, the feedback in each area was disappointing. With a 60% response rate, the general feedback for the pilot study was that the terminology used did make sense to the automotive respondents while the structure of the themes was also clear.

However, despite follow-up emails asking about content, the feedback remained very limited. The only two pieces of feedback were the comments that 'Research made sense' and 'I would not change anything'. Again, the feedback from two of the three academic friends who completed the survey was limited. The action taken to address this problem was to organise a meeting with one of the researcher's academic friends to discuss the details of the survey.

Once the pilot studies were issued, the researcher identified two main concerns. The initial concern addressed access, control and distribution, being that an open link to the questionnaire would be needed once it was ready to be issued to the wider group of participants. Once the problem was rectified within the set-up process, a third additional pilot or draft questionnaire was sent to ten additional respondents. As four of the ten responded to the survey, the issues about access control and distribution seemed to be solved. The next concern was how the data was displayed within the JISC analysis section of the platform. Rather than adjusting the whole questionnaire, once collated, reconfiguration of the data was decided upon as the solution to the problem.

Interestingly, the second pilot survey did throw up some significant concerns. Only one of the four respondents provided feedback on the questionnaire, suggesting that it was *‘Easy to navigate but content was more aimed at organisations which have already or are planning to introduce Industry 4’*. Overcoming this issue required a re-routing of an additional question set which focused upon opinions rather than existing facts. The aim of this question set was to ask the respondents about their opinion with regard to the possibilities of the level of adoption and impact if the technologies were not yet emerging within their organisation. The dual routing allowed the respondents to answer the questions both from an actual adoption and impact perspective, while providing insights into the potential adoption and possible impact of Industry 4.0 and the associated technologies.

Once the major changes were complete, the questionnaire navigation was tested by four members of the researcher’s staff. The changes were then confirmed with the supervisory group, while a draft questionnaire was then issued to an American-owned engine manufacturer. Six questionnaires were issued to members of the senior engineering team with a 50% response rate. The final reiteration of the questionnaire was then conducted with the engine manufacturer over the course of the survey’s duration.

In addition, the researcher’s further reading produced a 2019 article by Frank et al., (2019) which added an additional level of clarity in making sense of the complexities of Industry 4.0. The authors here presented a basic conceptual framework which categorised the associated Industry 4.0 technologies into two main themes. As discussed within the conceptual framework section of this thesis, the initial classifications presented by these authors further developed the conceptual thinking and framework presented by the researcher.

Once the framework was established, more focus and control (Fisher & Buglear, 2010) was provided over the empirical investigation. The focus provided justification for what the researcher was looking to determine in terms of data and findings. The outcome of this realisation was only a slight change in how the technologies were classified within the questionnaire, which allowed for a more guided and focused survey (Zheng et al., 2021). Draft 7 of the questionnaire survey was then developed and issued to the target audience, all of which is discussed within the research findings.

The decision was eventually made to derive the sample for the questionnaire survey opportunistic sampling. The researcher drew upon his personal business contacts to identify appropriate individuals from the UK automotive manufacturing sector. Why this approach was taken is discussed below within the challenges section. This approach eventually resulted in a sample size of 200 where 76 replied, giving a response rate of 38%.

4.6.3 Interviews: An Introduction

The following section provides justification into the original focus of the research along with a rationale for why semi-structured interviews were chosen and why they were most appropriate form given the three interview types.

4.6.4 Interview Sample and Process

The original idea behind the interview process was to engage with as many of the original UK equipment manufacturers (OEM's) as possible in 2021. This included the top-five companies by production volume, which were Jaguar Land Rover, Nissan, Mini (BMW), Toyota and Honda. The research plan was hence to target the key people for interview from within organisations other than Honda, as Honda UK was due to leave the UK automotive sector sometime in 2021

Following on from this, the plan was to engage with as many tier-one suppliers as possible throughout the UK automotive industry in order to devise an appropriate sample of the interviews. Tier-3 and third-party suppliers were intentionally excluded from focus, while the researcher's own network, two of the UK automotive alliances, the UK automotive body and automotive research centres became the focus. As highlighted earlier, by 2022 the UK had launched a Future of Manufacturing research programme to examine the future needs of industry as they tailor their operations to the digital future. Highlighted within this paper are a significant number of individuals from industry, academia and government who took part in this research. The researcher aimed to make connections with as many of these individuals as possible. General manufacturers from the researchers own networks were also included in the initial plans.

4.6.5 Interview Design

Given the exploratory requirements needed to yield the results of the interview questions, the most appropriate interview structure appeared to be the use of semi-structured interviews. The selection of semi-structured, exploratory interviews (Cassell, 2015) was thus intended to provide the flexibility required to adjust the questioning around the three principal themes, those of knowledge, the level of adoption and impact. While additional structure was required to address the research questions, it was decided that the openness of this structure would provide opportunity to explore the richness of the qualitative data gathering. The interview format was delivered through the Microsoft Teams online platform, allowing each interview to be recorded for further analysis.

Although face-to-face interviews would have been the preferred choice, due to the recent COVID-19 pandemic gaining access to these organisations was a challenge during these restrictive times. The method selected to collate this information was therefore to upload the Teams recording into Microsoft streaming where transcripts could be made automatically. The transcripts were then downloaded to Microsoft Word and printed off for deeper analysis.

The design of the interview guide was based upon the research themes of knowledge, adoption and impact. Hence, the design (Bell et al., 2018) was semi-structured but flexible in order to get the interviewees to talk openly about each of the topics of focus.

The preamble section of the interview consisted of a personal introduction, a research introduction and discussions followed by a confirmation of ethics overview which has been sent out, then deciding whether or not the interviewees had given their permission for the interview to be recorded. The objective of this section of the review was thus to set out the parameters for the coming interview and to ensure that whatever the interviewee disclosed then the ethical guidelines and protocols relating to anonymity would be followed.

The first objective of the general discussion section was to engage with the interviewee in an open discussion gauging their thoughts regarding Industry 4.0. The interview guidance notes highlighted that the researcher would ask the interviewee the following open question: '*Industry 4.0, smart/digital manufacturing. What are your thoughts?'* A delay tactic would then be integrated to ensure the interviewee had taken enough time to think about their response.

The second objective within the general section was to determine the participants' level of understanding by getting the interviewee to describe what Industry 4.0 means to them. The final general objective was to establish whether or not the interviewee thought that this new industrial movement was needed for today's competitive automotive and manufacturing sector. Although the use of a closed question was outlined in the interview guide, an exploratory *'Why?'* question was eventually used to further the discussion.

Looking at the knowledge section of the interviews, the set of objectives decided upon aimed to establish an individual level of knowledge and then gauge the business level of understanding around Industry 4.0, so deciding what associated technologies were thought part of this industrial movement. As with much of the research literature highlighted within this thesis, there was evidence that both the definition of Industry 4.0 and understanding its associated technologies were somewhat confused, entailing how important it was to determine whether or not this confusion also existed within industry. The final objective within the knowledge section was hence to determine which of the interviewees recognised a need to achieve further understanding of Industry 4.0 within their business circles.

In terms of designing the interview guide, the questions set aligned with the original objectives of establishing how the interviewees' organisations were adopting the technologies, and whether or not these decisions were a strategic initiative driven by the parent organisation. In addition, the objective was to determine where the organisations had begun their initial deployment of the technology. However, the feedback obtained from the survey pilot studies highlighted that this process had to change, being that one of the interviewees' feedback highlighted their perception that it was: '*Easy to navigate but content was more aimed at organisations which have already or are planning to introduce Industry 4.0'.* As with the survey, the interview approach was changed slightly to include actual adoption and potential adoption allowing interviews to be undertaken with individuals whose organisations were not yet on the journey to the digital future.

As with the adoption theme, the impact section needed to be modified in order to return the focus to the potential impact of Industry 4.0 upon actual organisations. The original objective here was to determine which areas within the interviewees' business had felt the biggest impact since the implementation of these technologies. This section was also designed to establish whether or not the interviewees' organisation had seen a shift in strategy since engaging with the technology. The final part of the original design of the impact section was to discuss the negative aspects of any implementation and the participants' opinion of the skills requirements of the future. However, as highlighted previously, the researcher was obliged to change tactical approach when the interviewees' host company was revealed not to have started their journey to Industry 4.0.

The final section of the interview structure was again designed openly to allow the interviewee to talk freely about Industry 4.0. A delaying tactic had then to be used to ensure the interviewee had time to think about their answer.

Due to the challenges outlined below, the decision was ultimately made to use opportunistic sampling. In summary, 28 individual connections were made from people within the researcher network which were mainly UK based automotive companies. Several individuals were also contacted within the general manufacturing sector. However, out of the original 28, only 12 interviews were completed eventually resulting in a 43% response rate.

4.7 Research Challenges

4.7.1 Introduction

The purpose of this section is to outline the overall challenges facing the project since research began. In providing a concrete section on challenges within the context of presenting the findings, the hope is that discussion of the obstacles and challenges that faced the study will provide more evidence justifying the approach eventually taken for the empirical analysis that delivered the final research conclusions.

From the beginning, several challenges faced the empirical research conducted in this study. These challenges were grouped into themes beginning with the lack of engagement and the technology push coming from the consultative and technology providers. The following section thus presents an initial discussion of the lack of engagement across the automotive sector within the UK. This discussion is then followed by an investigation of the 'noise' coming from the consultancy fraternity and technology providers in relation to Industry 4.0.

4.7.2 Lack of Engagement

It is indisputable that the process of academic research is rarely a straightforward task. Despite the best efforts of researchers to get people to engage, conducting questionnaires and interviews is never an easy activity to undertake. Similar challenges faced this research although these challenges proved trying for reasons unique to them, perhaps beginning with the lack of engagement with the various automotive bodies within the UK. On numerous occasions, several UK-based automotive representative bodies were contacted but on each occasion not one representative made themselves available to discuss Industry 4.0. In fact, of the four sector bodies contacted only a single person proving willing, largely because this individual had been the researcher's former colleague.

However, one of the main companies in the UK automotive sector did eventually take a call.

When discussing the questionnaire with the network, the main response was that it was something they wanted to do themselves as it was an opportunity for new business. However, when the researcher asked to speak to someone about the general level of engagement within the UK automotive sector, the general response was that no one individual was responsible. An automotive research centre was eventually contacted at the end of 21st February 2022 whose staff proved willing to discuss Industry 4.0. During a discussion on Microsoft Teams, it was highlighted that Industry 4.0 was not something that they were focused upon for the time being, or regarding which they currently had specialists within their faculty. Instead, the focus of the centre was alternative fuel and the transition to electric among other automotive research subjects. Although we had a very good meeting and it was a pleasure to meet the team, the outcomes anticipated were not achieved as Industry 4.0 was not something which they had been focusing upon.

Over a period of six months from January to June 2021, various people were contacted who had been found in the pages the UK Government Future of Manufacturing publication of 2014. Of those who did reply to the request for contact, the majority response was that because they were not experts in Industry 4.0 because they would not then be willing to discuss the document, despite being named on the document as attendees and advisors.

Several points can be taken from these findings. The question had already been raised of why the people shaping the future of UK manufacturing are not experts. While a significant finding, this does fall outside the boundaries of this thesis but what can be retained is that it seems that there is a lack of understanding of Industry 4.0.

This lower level of understanding is also evident within the researcher's own network. During the first phase of research, on eight separate occasions ex-colleagues from a UK-based OEM contacted the researcher explaining that they would not complete the questionnaire as they had not heard of Industry 4.0. Over the period of May-June 2021, the questionnaire was then sent to around 1600 people who form part of a UK-based regional automotive cluster. Reminders were sent out on three occasions asking people to complete the questionnaire, yet this cluster yielded a zero-response rate. A similar situation occurred with another regional cluster where only three people replied out of 300 companies contacted.

Due to this striking lack of engagement with regard to the questionnaire research, the research strategy was changed to focus upon the network of the researcher for the interviews. Now 28 individual contacts were made from within the researcher's network, coming mostly from UK automotive OEM's along with a selection of tier-1 and tier-2 manufacturers. Several individuals were also contacted from within general manufacturing. But of the original 28 envisaged, only 12 interviews were completed as the response from some of the network was that they did not know enough about the subject to have an interview.

Two individuals then explained that the company did not want to share any information with regard to what they were doing regarding Industry 4.0. One individual explained that '*the Management team have judged that we are not in a position to support your study currently unfortunately'.* All the information regarding anonymity and ethics had been discussed with the individual, but the leaders were not able to support the interview. The second organisation did not want to share any information suggesting that, this is an example of a group of people who simply wish to be seen to be doing something about Industry 4.0, and a conclusion which can also be drawn from the researcher's relationship with the company.

Going by the evidence outlined above, it then seemed arguable that the lack of general understanding of Industry 4.0 might be more widespread than initial thoughts which corroborates with what has been uncovered from within the adoption and impact section of the literature review. However, certain companies on opposite ends of the knowledge spectrum had genuine concerns regarding intellectual property; despite their professed immersion business school ethics, the people in these organisations would not engage with the researcher either. A final group expressed no desire to engage with the researcher for whatever reason despite their relationship with him.

4.7.3 Consultants and Technology Providers

In July 2021, the researcher attended a webinar hosted by one of the regional automotive clusters featuring a lead speaker from a global consultancy business and supported by the chief executive of the cluster. The focus of the webinar was digital manufacturing and how cluster members can engage. As expected, the overall webinar was sales-oriented, concluding with a subsidised readiness assessment given to all of the cluster members. Although the webinar was professionally executed, it was debatable whether or not it had done anything other than opening opportunities or the consultancy business.

At the end of the webinar, 15 minutes were left for questioning. The main theme arising in the attendees' questioning was around the case study and the proof of what had been implemented. They also discussed maintenance-based systems for plant equipment, particularly issues around monitoring. It was arguable in this instance that monitoring systems were indeed a part of the ecosystem discussed earlier, although taken in isolation they just remain monitoring systems.

The researcher then levelled a question at both hosts on quantifying their impact. Although one of the hosts avoided the question, he did provide an example of automatic replenishment systems which have been installed within the business of a cluster member. Again, it might be suggested that these replenishment systems were a part of the ecosystem, but they served in isolation as just another evolving technology. Neither host discussed the needs of the business in detail.

The problems arising here of a confusion or lack of knowledge around Industry 4.0 were also evident during an automotive expo which the researcher attended in 2019. Various speakers were allocated slots at the expo, one of whom was from a different global consultancy business. Generally, the sales messages from the consultancy business was one of ‘come join the revolution or be left behind’.

Further discussions took place throughout the expo with various technology providers, while the consultants highlighted that the tactics of many was to present ideas about the fear of being left behind. As one would expect, many of the technology providers were pushing their evolving individual technologies all of whom presented a different solution to solving industrial problems.

It might then come as no surprise that so many of the interviewees were ultimately confused when it came to questions of Industry 4.0. Early examples of the technology may perhaps have led to confusion as business leaders may not appreciate the difference between today's technologies and that of Industry 4.0. A pertinent example here was of one of the hosts who deflected the question on impact because he struggled to appreciate the difference himself. If the hosts themselves struggled to see the difference and advised businesses, then the journey through diffusion could well be said to have presented a challenge. The use of scare tactics in the second example then appeared to contribute little more than a marketing strategy for consultants and technology providers. Arguably, in both examples what was being demonstrated was essentially a technology push coming from each respective trade body or organisation.

4.7.4 Review of the Data Analysis

The primary software package used to gather the data from the survey questionnaires was the JISC platform, which provided a flexible solution enabling the researcher to integrate both open- and closed-question design into the questionnaire. This diverse approach to the questionnaire design provided extra validity to the questions asking the participants about knowledge, adoption and impact.

Tally charts were used for the closed questions grouping to collate the frequency of occurrence. Microsoft Excel then displayed the data in the form of a frequency chart. Each of the three main research questions addressing knowledge, adoption and impact were then grouped onto a separate dashboard to provide a summary of the descriptive statistics corresponding to each particular research question. Thus providing a summary sheet which aided with the data analysis.

The more open and descriptive questions used a coding structure set out in the technological classification work of Frank et al., (2019) whose work presents a theoretical framework proposing that the technologies associated with Industry 4.0 are split into two main functionalities (p. 4). Firstly, the 'front-end' technologies of smart manufacturing, smart products, smart supply chain and smart working are to be associated with operational requirements and market needs. The second type of Industry 4.0 technologies for Frank et al., (2019) are the base technologies of the internet of things, cloud, big data and analytics. These provide the intelligence and connectivity to the front-end technologies (Frank et al., 2019, p. 5).

As discussed during the literature review, based on the evidence found within the analysis of the literature the researcher added cyber physical systems to the base technology classification. Once the relevant groups of codes had been developed, frequency was selected as the measure used to collate the data. In terms of the tools used to display the data, Microsoft Excel was again selected while both the open and closed questions were summarised in the dashboard.

Rich insights were derived from these summaries of the descriptive statistics with analysis able not only to look trends and frequencies, but to validate the reliability of the data. The analysis conducted on these results is outlined within the findings section of the study.

4.7.5 Interviews

The process of analysing the interview data proved a time-consuming activity. Each interview was recorded on Microsoft Team, while a guide to semi-structured interviews was used to facilitate the discussions. Although the guide facilitated the discussions, on several occasions the interviewees wanted to express their opinions freely about Industry 4.0. While there was clearly a richness to the free-flowing information coming from the interviewees, it did provide a challenge in terms of cleaning, organising and analysing the data.

The initial interviews were recorded on Microsoft Teams and then transferred through to Microsoft streaming which has a functionality enabling transcripts to be developed from the recorded data. Although the functionality of this software package is good, the transcripts only provide a raw form of data. A follow-up process was then required to clean the data. This was a laborious task too but proved a critical step in establishing a more-or-less usable transcript.

The next step in the interview process was to organise the data into the three categories of research question: knowledge, adoption and impact. The final stage was to check the data once again for further validation to ensure that everything was organised and prepared ready for the transcripts to be analysed.

As with the surveys, the interview codes used corresponded to the three research questions in line with the technology classification framework set out by Frank et al., (2019). Microsoft Excel was used to organise and summarise all findings.

In order not to detract from the research questions, a separate section was added to summarise the vignettes given by the interviewees. Bearing in mind that the target population from which the interviewees were drawn comprised of industry professionals, the revelations emerging from the longer interview anecdotes provided an interesting contrast with the general findings outlined within the study. For instance, several of the interviewees were somewhat sceptical of the whole idea of Industry 4.0 and the potential implications of the impact.

4.7.6 Ethical Considerations

There are many in the academic community who argue that ethical considerations are among the most crucial aspects to take on when planning and conducting research. To cite two examples, Bryman and Bell (2011) list ten key ethical considerations for research, while Dudovskiy (2016) then provides a more condensed version of this (2011) list which outlines ethical consideration within research (Dudovskiy, p. 120). Although the afore-mentioned studies provide rich insights into ethical considerations for research, it is my belief as the researcher that the singular nature of the research questions then determines the most appropriate ethical approach to adopt.

Exploring Industry 4.0 as an emerging phenomenon has required careful ethical considerations, especially in the design of the research process. What proved to be one of the key issues at the forefront of ethical considerations was the sensitivity of the data regarding how organisation have dealt with the complexities of Industry 4.0. If, indeed, some organisations have instrumentalised the concept of Industry 4.0 as a movement to gain competitive advantage within their market, then there was the threat that accessing this strategic data might prove difficult and ethically questionable. It was thus crucial to take a careful ethical approach to the design of both research instruments. The obligation was then to ensure that both the questionnaire survey and the interviews were in alignment with Nottingham Trent University research protocols and ethical guidance.

Under this ethical obligation, each of the interviewees was given an informed consent document. This form provided a framework setting out 12 criteria aligning ethical considerations with the general purpose of the research and the nature of data collection and its disposal, as well as preserving the anonymity of the research participants.

The opening section of the consent form provided participant information of the research while outlining why the interviewees were chosen for the research. This section also supplied details as to why their specific organisation was chosen. For example, one of the organisations selected for the study is frequently seen as a leader in its field of automotive manufacturing.

The second section then outlined that the interviewees' participation in the research was completely voluntary, while also providing details about confidentiality and anonymity. In addition, this section included a discussion of how the research findings would be made available. The interviewees were made aware that, if required, they could obtain a copy of the findings which they were free to use to assist their organisation in its quest for digital transformation.

The penultimate section of the consent form provided a detailed overview of the advantages and disadvantages of participating in the research. The form then concluded with a signatory section to confirm whether or not the interviewee was happy to proceed with the interview.

Prior to their interview, each of the interviewees was asked if they were happy with the ethical guidance outlined within the consent form and were thus willing to move forward with the interview. This confirmation provided further validation of their participation in the research before moving forward with the interview itself. Each interviewee was also asked if they were willing for the interview to be recorded for further analysis.

Moving on to the survey design, this was structured in a similar way with the participants being provided with a general overview of the background to the research, along with a statement of the ethical obligations as outlined above.

Again, each of the respondents confirmed whether or not they were happy to take part in the research.

All data was managed by restricting access by having appropriate security arrangements, for example password protection for any files and for the laptop used as well as keeping the laptop locked away when not in use. These security arrangements were designed to ensure confidentiality.

Chapter 5 - Empirical Investigation

5.1 Introduction

The following empirical investigation has been structured around research questions. The rationale behind this decision is to allow a more structured approach to evaluation of the findings, enabling conclusions to be drawn based upon the posing of research objectives through these questions.

The first section of this chapter provides some general thoughts on Industry 4.0 taken from the interviews conducted. Generally the interviews were undertaken after the questionnaire or the two-phase process. Following on from this general introduction, the findings will be structured to determine: *What is understood by the term 'Industry 4.0'?* We did so firstly by drawing together the questionnaire findings and conclusions along with the interview findings and their associated conclusions. The overall purpose was to determine people's awareness and knowledge of Industry 4.0.

The next section then draws upon both the research questionnaire and the interview to determine: *To what extent are UK automotive and manufacturing firms adopting Industry 4.0?* The final research question was then the following: *What is the level of impact of Industry 4.0 upon the UK automotive and manufacturing sector?*
To answer this final question, we used the same structured method of questionnaire then considered the interview findings in order to draw conclusions.

Finally, we drew all the conclusions together to summarise them and provide corresponding answers to the research questions.

5.1.1 General Thoughts on Industry 4.0.

The question asking for the participants' general thoughts on Industry 4.0 was only used during the interview stage of the study. The rationale in asking an open question about people's general thoughts of Industry 4.0 was to gain some general sense of the views, perspectives and opinions of the interviewees. In answering the question in such a way freed from guidance or prompts, free reign was given to the interviewees to express their thoughts. Moreover, the design of the question allowed for free-flowing answers from the interviewees when giving their thoughts on Industry 4.0.

To add further depth to the research, three key sources from within academia, from a consultancy and from an automotive trade body were also interviewed to introduce a different context to the discussions. For the purposes of clarity, appendix 1.3 outlines the roles of these three key informants and nine other research interviewees. The key informants will hence be referred to as KI 1-3 and the research interviews RI 1-9.

These initial findings have led to two contrasting views being established among the research participants: firstly, those who have a more positive outlook; and secondly, those who are confused around the whole subject leading to a more negative view. A general description and discussion of these interviews then follows in this section.

To start off with, from the positive perspective a more senior manager (RI:1) suggested that *"this is not about connectivity it's about interconnectivity"*, while also stating that *"there is no limit to this power of the revolution, and the only limitation is our own imagination"*. The word 'imagination' was mentioned six times during this interview.

Interviewee RI:2 then suggested that *"If we can dream it, we can make it happen"* in support of pursuing radical or revolutionary ideas. Both statements were suggested by industrial professionals within their field of expertise emphasising the significant potential of Industry 4.0. The testimony of KI:2 also supported these thoughts in providing a vignette of a discussion with the plant manager of one of Europe's most productive car manufacturers. Here the interviewee explained that during this discussion they had focused upon the possibilities of Industry 4.0, particularly for live operative and cell efficiency monitoring. The consultant also reported that the automotive plant manager used the phrase the *'Holy Grail for manufacturing'* to describe the potential benefits of Industry 4.0.

It should be underlined that the consultant KI:2 does actually work for a large consultancy focused on Industry 4.0 whose business is based in Japan. The consultant’s role here is to sit in an advisory capacity to engage with UK-based automotive companies. While it should not be suggested that this discussion was illegitimate and should not have occurred, we need to maintain a degree of caution when considering these discussions. We might, for instance, be sceptical about the use of the term *‘the Holy Grail for manufacturing’* in the context of live operative efficiency monitoring.

In order to describe efficiency monitoring, the interviewee suggested here that *“The sooner the operator drops away from the actual it should be, it sends a message sender like an SMS or a message to the supervisor and tells him exactly which operator isn't performing well or at the right pace”.* However, it might be suggested that what is presented here is not uncommon within the context of modern manufacturing. Several of the researcher’s clients have experienced these cycle times and seen Takt time monitoring systems already in place.

Elsewhere positive ideas about interconnectivity and the possibilities of Industry 4.0 were prevalent in about a quarter of the interviewees, suggesting that they maintain a level of enthusiasm towards the capabilities of this phenomenon. What is interesting is that the two individuals who underline this “art of the possible” had spent a significant amount of time working within their relative industrial setting, suggesting that they were least likely to be taken along with any industrial ‘bandwagon’.

In fact, the interviewees generally viewed Industry 4.0 in a more proactive sense, suggesting that the only limitations to the technology was human imagination. Conversely, one opposite viewpoint revealed during the questionnaire came from a significant number of respondents who suggested that the technology is something that needs to be applied in order to keep up with the competition.

On the other hand, more negative views emerged from other interviewees whom even during the initial discussions identified concerns with the technology. Coming from an OEM background, one engineer (RI:6) suggested that when their company discussed Industry 4.0 he had had to ask, *“What does this mean?”* Participant RI:6 then explained that the responses he received were different every time while most, if not all of his staff still don’t understand what it is. These observations led RI:6 to conclude that within his company *“The term Industry 4.0* *is nothing more than a buzzword".* At the same time, RI:6 did offer a solution to the problem by suggesting organisations need to define what Industry 4.0 means to them.

However, this sense of confusion and lack of understanding was echoed by the majority of the interviewees, who suggested that the term *'Industry 4.0'* is a buzz word. As one engineering director from an OEM stated, *"I'll just call it the single bucket of buzzwords for industry".* In this context, the term 'buzzword' means jargon, or perhaps a fashionable or transient term.

The upshot of these early findings is that a potentially negative cause-and-effect pattern where one element has an impact upon the others might be developing in the companies outlined above. The upshot is that a general lack of understanding has affected how some individuals within this sample have engaged with Industry 4.0 so far. Interestingly, the organisation to which both interviewees belong was one of the few to confirm they have been engaged in a programme of learning and development. Yet a general lack of understanding about Industry 4.0 still appears to persist within this company.

The great majority of the interviewees (about 10 of the 12) then suggested that the language around Industry 4.0 has turned into a sale pitch and some technology manufacturers are even marketing products as *'Industry 4.0 compliant'*, when the reality is that these are the same products as before. One senior maintenance officer RI:3 suggested that *"Companies are pushing industry into markets based on old products – it's nothing new".* A small business owner RI:9 then stated that: *"Honestly, I am sick of hearing about it. It's being pushed onto us that much that every time I hear about it, I just switch off".* This opinion was also echoed by RI:6 suggesting that *"We are prone to be taken along with the hype of these types of initiatives without really understanding if it's the right things to do for the business"*. Again, the concept of the technology being *'flavour of the month'* was supported by others in the dialogue of the opening interview. For instance, RI:8 suggested that *"Industry 4.0 is just another flavour of the month just like TQM".*

One view that it is useful to take with the above findings is that there is a clear push coming from technology providers and certain other industry professionals.

However, to push the same old technology as *'Industry 4.0 compliant'* appears to constitute misleading marketing tactics on the part of the technology providers. In a similar finding to that identified in the previous paragraph, another small business owner RI:9 held the interesting view that these marketing efforts are now in abundance and may be starting to switch people off. This marketing momentum caused one company within our sample to invest without being able to recognise whether or not implementation of Industry 4.0 was the right thing for his business.

What was also revealed is that one large OEM has been allocated a significant budget from its parent company to spend on implementation. However, since very few within the business understand Industry 4.0, the engineering director explained that the existing budget has been spent on everyday typical engineering and maintenance software upgrades. These findings will be covered in further detail later in the discussion.

During the opening dialogue about general thoughts and impressions, several of the interviewees identified areas of concern with Industry 4.0. Participant KI:2 suggested that *"My worry within the UK is that industry will get left behind as industry 3 is still far from being achieved"*, explaining that UK industry needs to achieve level 3 of industry maturity before being ready for the transition to Industry 4.0. This finding would suggest that the adoption and impact of Industry 4.0 might be significantly longer for organisations who have limited amount of technology in place.

Similar concerns were echoed at a much more macro level by RI:1 who suggested that within Asia the general population are more accepting of change than they are in the West. That is to say, many Asian countries understand the need and benefit of digital transition much better than many companies in the West, particularly in the UK. RI:1 then provided a vignette on competition which is covered later in these interview findings.

Another very individual important point underlined here was the acceptance of a make-or-break factor to successful technology deployment. The researcher's own 17 years of lean training and consultancy put him in the place to recognise that this factor should not be underestimated. What could instead be suggested is that the lack of acceptance generally takes place on the lower levels of organisations.

However, personal experience suggests that this is not always the case, as the inability to accept change can lie with the organisational leadership. The evidence is rather that demonstratable commitment on the part of leadership is a prerequisite for successful implementation.

Interview participant KI:1 then suggested that there is an abundance of technologies available for industry to assist us in improving business performance. However, as isolated technologies go they are hardly revolutionary and are largely just the result of developing existing technologies. KI:1 provided the example of 3D printing and rapid prototyping, which are some 30 years old now but still regarded as evolving technologies. Here KI:1 suggested that aggregating these technologies and connecting them throughout the supply chain, then utilising data to responds to demand changes and to improve manufacturing capability, will shift the overall performance of the organisation. In his view, it is not individually evolving technologies that make up Industry 4.0 but aggregated and interconnected technologies.

These findings do align with some aspects of the work of Frank et al., (2019) and the conceptual framework discussed earlier, while the ideas about aggregation and interconnectivity are supported by the interviewee RI1 who suggested that *"This is not about connectivity, it's about interconnectivity",* which is again supported within the conceptual framework. We know from the literature, for instance, that a connected supply chain is a key aspect of Industry 4.0 (Lichtblau, 2015).

Interviewee KI:3 then provided a very practical description in answer to the opening question asking for his thoughts on Industry 4.0. The interviewee had made a visit to a factory in Germany in 2016 where he first heard the term 'Industry 4.0'. He explained that although the factory was a manufacturer of the product, it looked like a testing facility for technologies. The staff went about providing an explanation of the different technologies in use, such as cobots, visuals system, mood lighting for shift workers, hand-held devices for shift leadership. Finally, KI:3 summarised his visit to Germany by concluding that *"It was technology for technology's sake when other easier solutions are available*".

KI:3 further stated that what was evident from within the operation was the German-made integration infrastructure was connected to German machinery and technologies which were in turn connected to German hand-held devices. Here he used the analogy of the human body to summarise the interconnection of Industry 4.0, explaining that in Germany they have all the parts of the body working together to create this operating system, all of which are connected to a central brain function.

Interviewee KI:3 then contextualised these developments for UK manufacturers, suggesting that in the UK we only have part of the system which is not therefore connected to a whole. He further explained that the UK automotive manufacturers are predominantly foreign-owned, entailing that the purist vision for Industry 4.0 will be difficult to achieve within the UK. He instead suggested that UK manufacturers need a less utopian vision and should look at the implementation of Industry 4.0 from a different perspective in terms of what it might mean for individual sites to use the technology to solve problems.

Arguably, the analogy of the human body can provide further clarification for understanding the interconnections and relative complexities around Industry 4.0. The comparison with an organism is one way of defining Industry 4.0 which came up in our interviews, while other contributors refer to Industry 4.0 as an industrial ecosystem. In our opening interview which aimed to acquire general thoughts on the subject the majority regarded Industry 4.0 as being of use in solving organisational problems, with only KI:3 taking it to be a weakness.

Certainly, there is an argument to be made that solving organisational problems alone will not move organisations forward to push the boundaries of competition. Hence, there may be some truth in the claim that Industry 4.0 will not be achieved in its purest form in the UK, if 'purest form' refers here to all the parts of the ecosystem being aggregated, intelligently interconnected and aligned to business needs. With the abundance of technologies available, it is doubtlessly a weakness of UK industry not to be able to design something able to enhance its competitive edge. For many UK-owned SME's perhaps the opportunities provided by Industry 4.0 are more practical. After all, the evidence given from the first interviews discussed above is that "*the only limitation is our own imagination"* and *"if we can* *dream it, we can make it happen"*, entailing that the limitations lie with the individual rather than with the possibilities of what Industry 4.0 can achieve.

Interview participant KI:2 opened the dialogue with a realistic perspective on Industry 4.0, suggesting that *"business leaders within especially within the UK are struggling with where to start with the digital transition".* He further developed this idea by suggesting that many organisations have struggled to understand the basics of Industry 4.0, giving the example of one company who have manufacturing plants both within UK and France. He stated that the *"French facility leaders are engaging with maintenance strategies by upgrading old industrial technologies with new software which is providing improved operational performance without that significant investment is new technologies".*

KI:2 then suggested that the different ways of thinking demonstrated by industry leaders has improved asset availability for their operations. In contrast, the UK operations are still struggling to understand the basics, and here KI:2 emphasised that what adoption there has been in the UK has not started off in the right direction, so when it comes to quantifying any ROI from Industry 4.0 then the only conclusion to reach is quite a good number of stakeholders are struggling. Nonetheless, KI:2 concluded that Industry 4.0 has the potential to become as big as the lean movement which was introduced in the UK in the 1990's.

One very interesting finding is revealed here; namely, the inability to know where to start was a key element revealed in both the questionnaire research and the literature review. Participant KI:2 also suggested that his own network struggles to understand the basics behind Industry 4.0 in the UK, which corresponds to the findings from the knowledge questionnaire as well as the literature review. From the revolutionary ideas of Kagermann et al., (2013) and Lichtblau (2015) to the latest trend in manufacturing of (Kamble et al., 2020), then on to the research findings of Buer et al., (2018), all these contributions suggest that Industry 4.0 has evolved into a 'poorly define buzz word' rather than a key development in the next era of manufacturing. These conclusions are also supported by Kolberg & Zühlke, (2015) and Drath & Horch (2014), whose research suggests that Industry 4.0 is a catchy marketing name for existing technologies.

Nonetheless, all the authors mentioned above had varying views on Industry 4.0, so pinning down an agreed definition is difficult to achieve and would be more difficult again for people who are not engrossed in understanding this phenomenon. At the same time, the interesting comparison provided by KI:2 between a French plant and how the UK has engaged with the organisation of Industry 4.0 might suggest that the UK is lagging behind in engagement. However, the example of one plant does not represent a significant enough sample to draw meaningful conclusions.

To make a final remark regarding the possibilities presented by Industry 4.0 in comparison to the development of lean drive would present several areas for discussions. But is what is at stake here the question of clever marketing terminology, or a general belief that the impact could become so much more widely spread as became the case for lean drive? It has been suggested that the comparison with lean drive is a bold one because the outcomes do appear very similar, but the way it which its implementation was executed is very different. Lean drive utilised a people engagement approach involving relatively low costs compared to Industry 4.0, which involves a high technology and potentially high-cost approach to improving organisational performance. A high-cost technology strategy might create barriers to entry from many companies. Hence, what has also been confirmed by a number of interviewees is the importance of leadership in Industry 4.0.

5.1.2 General Thoughts - Summary

The initial findings suggest a level of confusion around the subject which arguably leads to two contrasting viewpoints. From a positive perspective, there are those who believe in the potential of Industry 4.0 and are enthused about the ‘art of the possible’. Others again believe in the potential of Industry 4.0 to be as big as the lean movement. These visions of the great possibilities of Industry 4.0 are particularly prevalent in around 4 of the interviewees, 2 of whom suggest that our own imagination is the only limitation to the possibilities of this phenomenon. They also view Industry 4.0 in a more proactive sense, with one interviewee suggesting that in a discussion with an automotive plant manager regarding live operative efficiency monitoring, the plant manager suggested that Industry 4.0 was the ‘holy grail for manufacturing’.

In contrast, the negativity surrounding Industry 4.0 does perhaps outweigh the positivity of the 2 out of 4 of the interviewees who see its potential. However, our conclusion from this section on general thoughts is that the majority of our research contributors actually see this as industry ‘hype’. Such comments suggest that the promotional efforts and publicity of the marketing functions within technology and consultants companies are making some interviewees view Industry 4.0 as perhaps a ‘flavour of the month’ or industry fashion. Other problems include the amount of jargon associated with this phenomenon which connects up with greater concerns about how the general lack of understanding has arguably affected how some individuals within this sample have engaged with Industry 4.0. Indeed, there has been a push from technology providers to market existing products as ‘Industry 4.0 compliant’, when the products are actually the same only remarketed.

The evidence here suggests that marketing efforts have been so strong that they are starting to turn people off the idea of Industry 4.0. On one occasion in this sample one participant stated that their organisation has invested without recognising whether or not implementation is the right thing to do for the business. The knock-on effect of this lack of judgement has caused individuals to update everyday software using the allocated Industry 4.0 budget.

Several of the interviewees also identified other areas of concern with Industry 4.0. Some of these concerns involve the suggestion that the UK is already so far behind that the country is less adaptable to change than other nations. Another area of concern is the capability of operational leaders to lead change in British organisations today.

A number of useful descriptions and analogies have also been cited to describe Industry 4.0 in the interview findings. The idea of an isolated evolving technology is nothing new, and certainly nothing more than the technologies existing today, but it is the aggregated, interconnected aspect which could make Industry 4.0 revolutionary. Although some were unable to determine it directly, the interviewees arguably recognised the confusion in defining Industry 4.0 and offered a description of what the industrial movements mean to them. These ideas align with the researcher's own views of Industry 4.0 which underpins the conceptual framework. The analogy of the interconnected human body suggested again by KI:3 demonstrates further clarification can be added our present understanding and can arguably be aligned with the view of KI:1 on the Industry 4.0 movement. It might then be concluded that KI:3 is able to bring a sense of realism to the general discussion of Industry 4.0 applications through a comparison of UK infrastructure with Germany, so suggesting a less utopian or purist vision for UK manufacturers.

What can be drawn from this section on 'General Thoughts' is that four main themes have started to emerge. Firstly, the use of jargon and buzzwords is causing a level of confusion. The second theme is that Industry 4.0 seems to be consultant driven in that push is coming from the consultative fraternity. A similar situation is apparent in the third theme which highlights that technology providers appear to be pushing the Industry 4.0 agenda while consultants and technology providers are using the buzzwords as marketing tactics to engage with the interviews on their journey to Industry 4.0.

The fourth and final theme that underpins these marketing efforts is the lack of clarity about what is being sold, as the evidence suggests it is 'old wine in new bottles'. Such remarks suggest that what is being sold is old technology repackaged, which does not entail that Industry 4.0 is in anyway revolutionary. There is also some recognition that leadership will need to play an important role in transitioning to Industry 4.0.

5.2 Knowledge of Industry 4.0

5.2.1 Knowledge Questionnaire Introduction

This opportunistic research sample was prepared using the researcher's own business network and contacts built up over 24 years of the researcher being involved both in the automotive and manufacturing sectors, and within the training and consultancy arena across the UK. The questionnaires yielded a 38%

response rate with a total of 76 people responding to the questionnaire. The reason why the questionnaire and interviews were kept separate is to explore the research questions in further depth and compare both sets of results.

The purpose of the knowledge questionnaire was to explore the level of awareness; that is,, the extent of the knowledge of what people from within a sample of the manufacturing and automotive sector understand about Industry 4.0. Here the existing knowledge was explored on several levels, beginning with general awareness, then describing Industry 4.0 which was followed by attempts to gauge the general level of understanding, before finally seeking to understand the associated technologies.

The focus of this research was to explore the level of knowledge further within a sample of the sector by asking the respondents to identify their levels of understanding. Further knowledge-mining was then undertaken, which is presented below, and this time the respondents were asked to describe what they believed to be Industry 4.0. The main aim of this section of the research was to move the analysis on while providing more depth of analysis around general levels of understanding. The analysis then focused upon which technologies are associated with the Industry 4.0 and the level of understanding surrounding them.

The presentation of the findings here makes use of a graphical format to show how frequently the technologies were mentioned within our questionnaire. The technologies were then grouped into a conceptual framework of smart and base technologies. Analysis then sought to uncover the level of understanding for each of the technologies categorised in the framework. The final section of the knowledge findings then presents the sources where the respondents acquired knowledge of Industry 4.0.

5.2.2 Knowledge Questionnaire

The initial awareness question sets out to determine whether or not the respondents had heard of Industry 4.0. The findings in this general awareness section found that 53, which represents 70% (n=76) of the total respondents in the sample, were aware of Industry 4.0 while 30% (23) were unaware, details of which are discussed below. It might be suggested that these findings were of significance given that the automotive and manufacturing sectors were targeted, which are arguably the sectors most embracing change and innovation. Moreover, the respondents targeted in the sample are individuals who are likely to be engaged in pushing such initiatives within their respective organisations.

Further analysis then established that of the 23 respondents who have not heard of Industry 4.0, 7 are from general manufacturing and 6 from the automotive sector. Again, this is a significant finding given that the automotive and manufacturing sectors are perhaps the sectors where the respondents are more likely to embrace the technologies of Industry 4.0. The remaining ten respondents came from aerospace and food manufacturing. In total, 23 respondents have not heard of Industry 4.0.

As previously highlighted within the literature review, Industry 4.0 has been around since 2011 in Germany (Kagermann et al., 2013) which means that at this point in the research, the phenomenon has been 10 years in the making. Although the first ideas were developed in Germany, the fact that many within the UK's target industries have not heard of Industry 4.0 is surprising. This finding is again more surprising given that in 2013 the UK government launched the 'Future of Manufacturing' initiative which embraces digital manufacturing. Despite the UK government's initiative and the ones mentioned within the literature review (along with the media attention associated with this phenomenon), there are still sections of the UK automotive and general manufacturing unaware of the Industry 4.0 movement. In fact, the researcher was contacted by individuals from within his network on 8 separate occasions who explained that they would not take the questionnaire as they had not heard of Industry 4.0. Consequently, what is presented in the questionnaire may understate the actual lack of awareness within the UK automotive and manufacturing sectors.

Arguably, the findings presented here are of considerable significance for which there could be a number of reasons. One of these reasons might be that Industry 4.0 technologies are limited to only a small number of the more innovative manufacturers. One other variable to consider is the idea that many of the UK automotive manufacturers are foreign-owned, where implementation efforts have begun within their country of origin while in the UK there has been delay in implementation efforts. However, these are merely suggestions, none of which can be confirmed or refuted at this stage in the research.

On the other hand, the researcher does offer an opinion of why it is of no surprise that 30% of the respondents have never heard of Industry 4.0. The researcher's own network is one of consultancy and learning and development professionals. The nature of this fraternity is to explore opportunities to engage with organisations. Perhaps this has caused the researcher to have been taken along with the initial hype associated with Industry 4.0. Hence, if this 30% figure was proposed at the beginning of the thesis, then such findings would be of a significant surprise to the researcher.

Further analysis then established that 23 of the respondents who have not heard of Industry 4.0 had 16 years or more experience within their respective sectors. This finding suggests that a significant number of experienced professionals have still not heard of this digital movement within their relative sectors. The link between years of work experience and age range was then considered. Here it may be stated that the younger professionals were more influenced and engaged with technological development. The findings here were that almost 3/4 of the total respondents who had not heard of Industry 4.0 were aged 46 or over. However, further analysis overall showed that the respondents with an age range of 46 and over comprised 58 of the total 76 respondents.

The data was then analysed to determine whether or not the country origin of the parent company had any significance within the findings. Could it be determined whether or not one country in particular was pushing the agenda further than the others? The findings suggested that the 'no' respondents were not only from UK-owned businesses, but also Dutch, American, and Japanese-owned businesses. These findings seemed to imply that the country of origin of the parent company was not of significance. Although this is difficult to justify as Industry 4.0 is a German-born initiative, perhaps an area for further analysis would be to determine whether or not German owned companies are now at the forefront of implementation efforts.

In summary, despite the 10-year history of Industry 4.0, the suggestion by many that this technological phenomenon constitutes the fourth industrial revolution and the effort of many consultancies and technology providers, 30% of the respondents within this sample have still not heard of Industry 4.0. If the eight respondents who contacted the researcher explaining that they would not take part in the survey were included in these findings, then the 30% who claim to be unaware would increase to a significant 41%. In that case, the initial lack of awareness of Industry 4.0 within the UK automotive and manufacturing industry might have been somewhat underestimated. These findings are a further surprise given the target respondents for the survey were people from within the automotive and manufacturing sector and are individuals who are likely to be involved with implementation efforts. Given that many authors Kagermann et al., (2013), Lichtblau (2015) and Schwab (2016) suggest that this is the fourth stage of the industrial revolution, a significant 30% or 41% (which include the individual who have not taken the survey) within this sample had not heard of Industry 4.0. Arguably then, the reality is much different to what many are suggesting in the survey if, at this initial stage of research, Industry 4.0 is thought to be anything like a revolution. It may therefore be suggested that the term revolution is overstated.

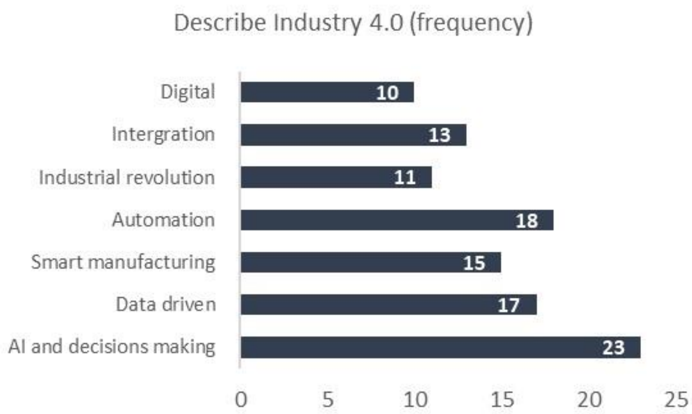
5.2.3 Levels of Understanding in the Questionnaire

To ensure that the depth of knowledge would be explored in enough detail, the following section asked the respondents to describe Industry 4.0. From a high-level perspective, when the respondents were asked about their level of understanding the findings suggested that 13 have a limited or no understanding of the concept, 30 have a basic understanding of it while 10 claim to have an advanced and extensive understanding. It may be suggested that this advanced level of understanding equating to 13% (n=76) of the total respondents is unsurprising given the evolving nature of this research. The technological complexities, associated media marketing, lack of clear definition and general confusion are all factors contributing to such a small number of respondents understanding Industry 4.0.

Having said that, there seems to be a small but distinct number of pioneers or leaders who seem to be engaging with Industry 4.0. Interestingly, the ten individuals in question equate to 13% of the total sample. If these findings focused on adoption rather than knowledge, then comparisons can be made to the work Rogers (1962) on innovation diffusion. Based upon the findings, it might be suggested that at this point the terms used to describe Industry 4.0 are somewhat exaggerated in relating it to an industrial revolution. Although evolution rather than revolution would arguably be a more appropriate description, clearly some are making efforts to engage with Industry 4.0.

Asking the respondents for their level of understanding has provided a starting point for understanding their knowledge of the phenomenon. However, what is arguably at stake here is their own perception of what they believe Industry 4.0 is. Therefore, the following analysis conducted in this section will check this apparent level of understanding in asking the respondents to describe Industry 4.0. A summary of the frequency distribution of their answers is presented in Figure 5.1 below, giving the sample of the 53 respondents who have heard of Industry 4.0 (n=53). When asked to describe Industry 4.0, the responses touching on AI and decision-making had a much higher frequency. In fact, in terms of frequency ‘automation’ was mentioned 18 times followed by ‘data driven’ which was mentioned 17 times.

Figure 5.1: Frequency chart describing Industry 4.0



Clearly, what is presented in Figure 5.1 can serve to provide a much richer insight into the respondents’ level of understanding of Industry 4.0. Arguably, what many of the respondents are referring to is little more than today's evolving technologies taken in isolation. On the other hand, the use of the word 'integration', which has a frequency of 13, remains a key factor in defining Industry 4.0. It may be suggested that these finding do corroborate with the small number of respondents who suggested they had an advanced understanding of Industry 4.0, as highlighted earlier and in terms of what they had uncovered from within the literature.

Both 'smart' and 'digital' are perhaps more general terms associated with Industry 4.0. However, the use of the word 'integrate' might be thought of as a differentiator between today's evolving industrial technologies and that of the Industry 4.0 movement. The terms 'AI and decision-making', 'automation' and 'data driven' are all elements within the system. However, without giving examples of aggregated, integrated and intelligently connected systems then what the respondents have presented are simply examples of today's evolving technologies. Furthermore, the mention of 'industrial revolution' is arguably little more than a marketing term which might suggest that some research participants are getting pulled along with the marketing hype surrounding Industry 4.0

While the frequency distributions do provide one perspective on how to make sense of the data, further detailed analysis into the use of open questions may also provide a rich source of information. To explore this level of understanding further, an open question structure was then used. This question asked the respondents to describe Industry 4.0 in their own words. This request for more detailed analysis then led to three different levels of understanding in describing Industry 4.0. First, the more advanced level of understanding consisted of only three descriptions:

> *"A fully integrated business made up of integrated factories - everything and everyone has access to the network. The layers of the business are integrated and operate based on data and information from each and all of the other layers, in real time. Machine learning technology is implemented to predict future outcomes based on past patterns and current state. AI recommends operational adjustments to improve future outcomes. Stakeholders have a view of the business state now, in the future*

and can decide to make real time data-based decisions to improve the output of the OT on the shop floor."

"Application of digital and smart technologies to automate, integrate and autonomise traditional manufacturing process and practices. Adoption of M2M communications, IIOT and advanced data management and analytics to accelerate process autonomy and improved decision making to maximise OEE."

"Smart Manufacturing means bringing the elements of smart technology – sensing inputs, computing power, always-on connectivity, artificial intelligence, and advanced data analytics – to the traditional production process. Used collectively, these technologies should help teams unlock new opportunities to accelerate development, reduce waste, and increase transparency of the supply chain."

The quotes above appear to indicate a sophisticated or advanced level of understanding, which is in marked contrast with the opinions cited below:

"Unable to comment as I've not heard of them despite having worked for GM, PSA, Ineos and Volta."

"Nothing other than more companies are becoming more automated."

The third level of understanding includes everything else which sits between these two opposite viewpoints, as is to be found in the following statements:

"*My knowledge of Industry 4.0 is very limited. The only thing I know is that it's all about moving forward and using technology to advance your business and bring it to the next level. I think AI has a part to play in this."*

"The 4th Industrial revolution utilising the most updated technology both smart and digitalised, autonomous manufacturing and the next revolution of manufacturing."

These initial descriptions derived from the open question given in the interviews can be interpreted to mean that the respondents seem conversant with the nature of Industry 4.0. The depth of detail given in the descriptions about integration, networking, connectivity and integration with today's technologies suggests a more advanced level of understanding. Of the total number of respondents (n=76), only 8 appeared to base their description have a deeper level of understanding. Of particular interest here is the description given by one respondent, who states that if *"used collectively, these technologies should help teams unlock new opportunities to accelerate development, reduce waste, and increase transparency of the supply chain."*

For the researcher, this notion of collective technologies unlocking opportunities reveals the real potential of Industry 4.0. It is hence the researcher's view that it is not the isolated, evolving technologies but the collective connected technologies which could be revolutionary. The respondent's description suggests that he has a deeper level of understanding, although further analysis of the questionnaire data reveals that the more advanced descriptions come from some consultants, or people directly involved in pushing 4.0 technologies into industry.

At the opposite end of the scale, a small number of the respondents offered terms which arguably demonstrate a lack of knowledge. One of the respondents had not heard of this phenomenon even though he has a significant amount of experience operating within the automotive sector. Another respondent referred to increased levels of automation but then demonstrated a significant lack of understanding.

Linking the frequency distributions shown in Figure 5.1 to the more descriptive evidence, it may be suggested that most of the respondents talked around the subject so demonstrating a limited understanding. Perhaps the respondents did actually recognise that Industry 4.0 has something to do with advances in digital technology, but they struggled to understand how. Conducting further analysis, the researcher gauged that some respondents indeed struggle to recognise the differences between today's technologies and that of Industry 4.0. One conclusion that can be drawn from this data is then that the majority of the respondents expressed ideas about the possibilities of Industry 4.0.

Given the variation in the questionnaires and description of the Industry 4.0 movement, the findings may be interpreted to entail that Industry 4.0 has different meanings for different people. Some respondents answered the question with technical responses rather than using general descriptions, suggesting that they focused upon the outlining technologies rather than providing a more holistic view. Although it is too early to validate this finding at this point of the investigation, there are signs here that some of the respondents use “buzzwords” associated with Industry 4.0. For the moment, it suffices to say that much confusion or at least ambiguity exists in these initial efforts to gain an insight into the respondents’ understanding of Industry 4.0.

Whether or not this ambiguity could be called a trend, the confusion around these ideas is echoed in the literature; namely in the revolutionary ideas of Kagermann et al., (2013), Lichtblau et al., (2015) and Buer et al., (2018 p. 3) who suggest that Industry 4.0 has evolved into a *“poorly define buzzword”* for developments in the next era of manufacturing to suggest that, in fact, we are seeing nothing new except the alignment of existing technologies. Kolberg & Zühlke (2015) and Drath & Horch (2014) also suggest that Industry 4.0 is a catchy marketing name for existing technologies, while Gillani et al., (2020) conclude that digital manufacturing technologies constitute a relatively unexplored phenomenon requiring further exploration (Gillani et al., 2020).

Preliminary efforts to determine the level of understanding present in the questionnaires duly uncovered a limited level of understanding on the part of the respondents. The conclusion to be drawn here is that three levels of understanding exist, where the first level seems to demonstrate detailed knowledge but also include detailed description provided by the respondents who actually know very little about Industry 4.0. Of the 53 respondents, 8 might be described as possessing a deeper understanding based upon their description of Industry 4.0, which is fairly consistent with the previous findings. In reality, most of the respondents sit between these two extremes, describing elements associated with the movement but perhaps missing key aspects of what is different between today’s evolving technologies and Industry 4.0.

Overall, it is the view of the researcher that what is actually being described in these questionnaires are the possibilities of Industry 4.0. Rather than describing what Industry 4.0 was about in general, many respondents focused upon the technologies themselves using terms associated with Industry 4.0. At this point in the research then, the findings support the conclusion of the previous research undertaken by Buer et al., (2018), Drath & Horch (2014), Gillani et al., (2020) and Kolberg & Zühlke (2015), which is that much confusion still exists about Industry 4.0.

In summary, from the evidence gathered it might be suggested that the level of knowledge and understanding around Industry 4.0 is of significance when, from within the sample, 30% of the respondents had still not heard of Industry 4.0. As pointed out earlier, the reality is that this group could be even larger as a further 8 individuals then contacted the researcher explaining that they would not complete the questionnaire due to having no understanding of the topic. This admission came in spite of the suggestion that Industry 4.0 is the 4th stage of the industrial revolution. In fact, it was revealed that when the respondents were asked about their level of understanding, the findings suggest that 13 have a limited or no understanding, 30 have a basic understanding and 10 claim to have an advanced and extensive understanding.

When mining for further clarification through the descriptions, 8 descriptions can be highlighted as constituting more advanced understanding, while 13 of the respondents suggested Industry 4.0 has to do with integration. Here the findings do somewhat corroborate in that they reinforce the idea of a small but distinct group of pioneers who seem to have a more detailed understanding than the overwhelming majority. All the same, the majority of the respondents do seem to have a basic to limited understanding of Industry 4.0.

5.2.4 Technologies associated with Industry 4.0

This section explores awareness of Industry 4.0 from a technology perspective with the objective of exploring just how much the research participants really understood Industry 4.0. The questionnaire approach here is slightly different as it explores knowledge from a technology perspective, firstly by presenting an open question to the respondents about which technologies they associate with Industry 4.0, the results then being presented in a frequency chart. To add a further level of analysis these associated technologies were then grouped into the classification suggested by Frank et al., (2019). The following section breaks down the front-end and base technology groupings in asking the respondents to state their level of understanding of each of the categorised technologies.

The use of analogy here might be the best way of understanding why a general level of technological understanding is of importance within this research context. At the basic level, in order to bake a cake an individual will need to comprehend firstly what cake they are trying to make. Secondly, the individual will have to decide upon the key ingredients needed to make that particular cake. Thirdly, he or she will have to determine in what sequence the cake needs to be made to ensure the specified outcome is achieved. In the case of Industry 4.0, the cake recipe represents the needs of a business, where the organisational leaders need to understand which outcomes are specifically required for their business. Put directly, what are the strategic outcomes that business leaders need from the introduction of the digital technologies?

Within the conceptual framework of this study, these business outcomes are to be categorised as business needs. The ingredients then constitute the abundance of today's evolving technologies, some of which are outlined within the research of Frank et al., (2019) in terms of the categorisation of front-end and base technologies. The final part of the cake analogy concerns method and how a company should drive a specifically designed sequence or strategy for technology implementation able to achieve the predetermined outcome sought by the business. Here, it is not a single ingredient that makes the cake but the right selection of ingredients serving as the recipe for achieving the specified outcomes in terms of how the ingredients are aggregated together in a predetermined way.

Arguably the ideas of Industry 4.0 are conceptually very similar. What is required is not a single technology but a carefully, strategically selected aggregate of technologies connected intelligently. In the view of the researcher as to what makes up Industry 4.0, this aggregate of technologies then has to be executed strategically to achieve a predetermined outcome. Why establishing this viewpoint is of importance at this point of the thesis is that if the respondents do not achieve a level of understanding of the technologies, then the correct selection or ‘ingredients’ will arguably be difficult to achieve. There are obvious ways around this problem, such as cross-functional collaboration, but to revert to the first research objective of determining the level of understanding within the sample, it is first important to establish the level of understanding of associated technologies in the study sample.

Figure 5.2 displays the frequency responses to an open question asking the respondents which technologies they associate with Industry 4.0. The technologies mentioned 8 times or more are displayed within the chart. Out of the 8 technologies highlighted in Figure 5.2, 3 of the base technologies in the conceptual framework are frequently mentioned. The internet of things then has a frequency of 18, big data 17 and cloud technology at 13. As previously discussed, the base technologies are perhaps a more recent development, especially within the context of manufacturing. If they were then aligned and used with the aggregated existing industrial technologies, they might arguably make Industry 4.0 a reality.

Figure 5.2: Frequency chart of technologies associated with Industry 4.0

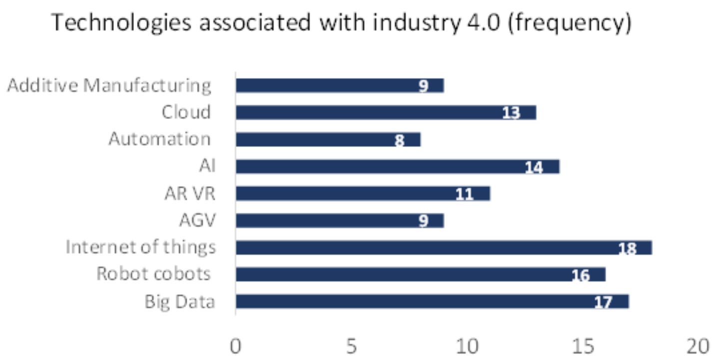


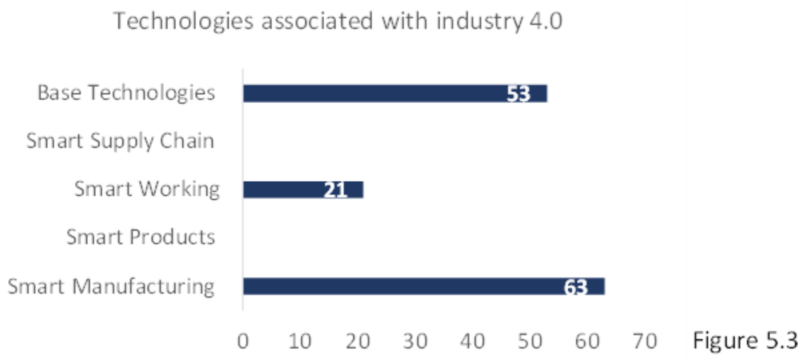
Figure 5.2

The above findings demonstrate a level of awareness of some of the technologies associated with Industry 4.0. Based upon the categorisation suggested by Frank et al., (2019) presented in Figure 5.2 above, 3 of the 9 technologies may be said to be more closely associated with Industry 4.0: the cloud, internet of things and big data. Arguably this finding corroborates the previous findings insofar as there seems to be a number of respondents who have a sound understand of Industry

4.0. The other 6 technologies listed here are arguably little more than today's existing but evolving industrial technologies. However, the evidence does suggest a level of awareness of some Industry 4.0 technologies. Interestingly, the cyber physical systems which Kagermann et al., (2013) suggest that Industry 4.0 are built upon are not mentioned at all in the respondents' answers, details of which will be discussed below.

Figure 5.3 builds upon the work of Frank et al., (2019) insofar as the technologies are categorised in terms of frequency and the base technologies are mentioned 53 times by the respondents. The smart working technologies are then mentioned 21 times, while the smart manufacturing technologies are cited 63 times by the respondents. Although this categorisation is not a primary objective within the empirical section of the thesis, what it does provide is a structure to assist in clarifying the technology groupings. As demonstrated in frequency chart 5.3, smart manufacturing technologies were most frequently discussed by the respondents. Arguably, what the respondents demonstrated then is that many of them are unaware of the connected possibilities of Industry 4.0. One reason why both smart supply chains and smart products are not discussed is that people may be unaware of the possibilities of connecting suppliers through the transformation process and then connecting them to the end user. If, as Kagermann et al., (2013) suggest, Industry 4.0 is all about connectivity and integration then perhaps what can be concluded from Figure 5.3 is that the concept as the respondents understand it does not currently exist outside of standard manufacturing. According to the rationale set out by this study, this finding might suggest a lack of understanding of Industry 4.0 on the part of the respondents within the sample.

Figure 5.3: Grouped technologies aligned to the conceptual framework



The final test of knowledge use builds upon the categorisation of Frank et al., (2019) in asking the respondents for their level of understanding around both the base and smart technology groupings. Added to the base technologies grouping are now cyber physical systems, as discussed previously within the technologies section of the thesis. Beginning with a general overview, what can be drawn from Table 5.4 is that the level of understanding on the part of the respondents would appear to have a limited to basic (principle) understanding of all the technologies within the base technology grouping.

Table 5.4: Level of understanding of base technologies – cyber physical systems added (n=76)

	No understanding	Limited understanding	Understand the principles	Understand most of the technology	Fully understand & how it's applied
Cyber physical systems	18	22	9	4	0
Cloud computing	4	15	21	13	0
Internet of things	5	17	22	8	1
Analytics	3	19	27	4	0
Big data	11	17	20	4	1

Figure 5.2 establishes the internet of things, big data and cloud computing as the technologies that the respondents associate with Industry 4.0, entailing the respondents recognised that the internet of things, big data and cloud are technologies they associated with Industry 4.0. However, looking at Table 5.4 above, it may be concluded that the respondents did associate the aforementioned technologies with Industry 4.0 but their level of understanding is still basic to limited when comparing both sets of data.

Table 5.4 also shows that 13 of the respondents suggested that they understood most of the cloud technologies, which is the highest level of understanding of all the technologies categorised within the base technology grouping. Any corresponding analysis cannot be confirmed or refuted at this stage, but it might be suggested that the respondents are focused only on cloud-based software systems and not the cloud context of manufacturing. As is outlined briefly in the technologies section, cloud manufacturing is such a vast subject area that understanding most of the technologies would arguably constitute a research paper in itself.

However, from a more positive perspective there is evidence to suggest only a small number of respondents understand most of or fully understand the technologies associated with the base technology grouping. What is of significance is the average across the grouping who understand most or fully understand equates to 9% in these two groupings. This finding appears to become consistent as the survey progresses and does support the previous findings in suggesting that there are a small but distinct number of individuals who seem to be actively engaged in understanding the technologies of Industry 4.0. Perhaps these individuals are the pioneers of Industry 4.0 from within the research sample (n=76), which does corroborate with the previous findings.

Table 5.5 below outlines the front-end technology grouping suggested by Frank et al., (2019). The technologies associated with each grouping can be found in Appendix 1.0. Any ambiguity from the respondents should be overcome here as the information provided outlined which technologies fit into the relative front-end categorisations. Looking forward to the discussions regarding the front-end technologies, it is the view of the researcher that the evolving technology of today presented by Frank et al., (2019) is being referred to by this grouping.

In fact, in terms of what is presented within the front-end technology grouping presented by Frank et al., (2019) and displayed in Table 5.5 here, all of the above appear to constitute today's existing but evolving industrial technologies. The level of understanding of these technologies was clearly basic to limited, with basic or principle understanding spread across the four front-end technology groupings. However, to stick with the same calculations of the previous table, what has been uncovered here is the small number of respondents who seems to be pushing ahead in understanding this technology grouping. The two groups that understood most or fully understand the technology equated to 12.5% (n=76) of the sample as an average over the four technology groupings. This result does differ for the 9% thread which was highlighted previous but, in essence, the finding has already been anticipated in the notion that these front-end technologies are nothing more than today's evolving technologies, regarding which the level of understanding is likely to be more. One perspective to be considered here is that if these are to be thought of as the technologies of today, then it is puzzling why more respondents did not understand most or fully understand the technologies. One consideration is that respondents might not understand them within the context of Industry 4.0.

Table 5.5: Level of understanding of front-end technologies (n=76)

	No understanding	Limited understanding	Understand the principles	Understand most of the technology	Fully understanding & how its applied
Smart working	10	16	16	9	2
Smart supply chain	7	23	16	7	0
Smart products	7	13	23	8	2
Smart manufacturing	6	15	21	9	2

However, it is possible to take the different perspective that for a single person to know about all the technologies within the groupings is perhaps unlikely if not an impossible achievement. One additional factor to consider here is the role that each of the respondents occupy within their respective companies. It may then be argued that the knowledge possessed by the respondents will be more advanced in relation to the technologies with which they are involved in their professional role. To take one example, an engineer who is responsible for a supply chain is more likely to know about supply chains than smart working technologies. However, with such an abundance of technologies extended across the entire value chain it would be almost impossible for a single person to know them all. What this reality instead suggests is that cross-functional collaborative efforts may serve as an enabler for organisations looking to transition into a digital future.

To develop the above point, the claim to be made is that internal collaboration can allow organisations to improve their level of engagement and so assist individuals in accepting the technologies into their business. External collaboration can then allow organisations seeking to transition to the digital age to access a much wider knowledge pool of assistance in the learning journey. Outside of the engineering and maintenance technical roles, the focus for business leaders perhaps needs to be on technology capability rather than technicality. Arguably these drives towards internal and external collaboration may lead to a quite open approach towards how business might engage with digital innovation.

In sum, what has been uncovered within this section on technologies is that the majority of the respondents have a clearly very limited knowledge across the technology groupings. Conversely, a small but distinct number of respondents appear to have a more advanced level of understanding, which is again a common theme running through the findings around knowledge. The sets of findings across the areas of general knowledge and technological arguably are both consistent insofar as the knowledge is fragmented with some ‘early’ pioneers who were pushing the knowledge boundaries more than most.

As discussed, for one person to understand all the associated technologies is arguably unrealistic. However, without a general level of understanding of the technologies then diffusion may be much longer and perhaps less likely to succeed. These discoveries do support the findings within the initial section of knowledge recalling that despite this industrial movement being suggested as the next industrial revolution, evolution is arguably a more accurate term at this point within the research.

5.2.5 Industry 4.0 Information Sources

The final part of the questionnaire analysis seeks to determine how the respondents have acquired their information on Industry 4.0. These information sources were identified by the researcher based upon his prior experience and consist of consultants, trade magazines, internal communications and personal research among other sources. Table 5.6 below outlines in ranking order the top, second and third choice sources of where the respondents acquired their information. The first top 3 ranking sources for the respondents within the sample are: internal communication, consultants and personal research. What is arguably being presented here is information pushed onto the sample respondents by their own organisations and consultants, suggesting that some organisations within the sample are taking an active role in communicating internally about Industry 4.0.

The data highlighted in the table below also shows that consultants are the joint-first information source and are the only source to feature in all three areas. Appendix 1.1 provides links to the websites of various consultancy businesses which outline their organisational efforts to engage with Industry 4.0 or variations upon this theme. With Industry 4.0 being on the agenda of many consultancies, it is no surprise that consultants feature in all 3 of the information sources suggested by the respondents in the sample.

Placed within the first-choice category then, personal research is perhaps the first occasion where we can suggest that the respondents have been actively researching the subject of Industry 4.0. Linking the previous tables showing levels of understanding to Table 5.6, it appears that the level of understanding demonstrated here is still limited despite the effort of internal communications and consultancies. Perhaps what the ‘personal research’ category then represents is that the respondents within the sample still require further explanation to understand this phenomenon, using personal research to bring further clarification. Linking these findings to the data within the literature review, it can be seen from the evidence presented by Kamble et al., (2020) that, since 2013, the number of publications on Industry 4.0 has almost doubled yearly leading to a disorganised and confused body of knowledge (Sestino et al., 2020a). Despite these combined efforts, the level of understanding within the sample is still basic to minimal, which is causing respondents to do their own personal research.

The presence of trade magazines within the second-choice category is perhaps another example of how information is being pushed onto the respondents from various sector-specific magazines. Appendix 1.2 provides an overview of what sector-specific magazines and industry websites are writing about Industry 4.0. In 2013, the UK Government launched the 'Vision for UK Manufacturing' initiative to provide a strategic look at UK manufacturing as far ahead as 2050 (Government Office for Science, 2013). This initiative then took digital manufacturing to be an enabler of the vision for manufacturing and its supply chains. Perhaps with the UK government then viewing digital technology as a strategic initiative worth pursuing for industry, technology providers and consultancy business were likely to increase marketing efforts to assist with revenue generation.

From an alternative perspective given that personal research scores highly in terms of first and second choices, this might suggest that these individuals are well-motivated to learn something new about their profession. From the evidence gathered, it may then be suggested that the respondents are actively engaging with their trade magazines and are so continuing to seek out further information about Industry 4.0.

Table 5.6: Information sources

Ranked Sources of Information	**Frequency**
First Choices	
Internal communications	11
Consultants	11
Personal research	8
Second Choices	
Trade magazines	17
Personal research	13
Consultants	9
Third Choices	
Consultants	15

Trade magazines	14
Internal communications	14

It is the researcher's view that today's industrial news, websites and magazines are awash with discussions of Industry 4.0, digital or smart manufacturing in some form or other. However, it is the consultancy and technology fraternity who are pushing their own agendas channelled through trade magazines, websites and industry media which are adding to the hype. What these findings indicate is another example of the media hype associated with Industry 4.0. This idea is echoed by a recent blog by Professor Christoph Rosser, stating that:

'I believe Industry 4.0 is profitable for software vendors, service providers, and consultants, but only sometimes for the actual manufacturer.'

(Christoph Rosser, (2021) 'Ten years of Industry 4.0 – Quo Vadis?')

As previously highlighted, this level of scepticism is prevalent throughout the research literature. Further analysis was then conducted to address the significant level of scepticism that arose during the interview section of this thesis.

Given the quantity of information pushed from the consultants and trade press to link these conclusions to the earlier findings is to conclude that almost a third of the respondents are still unaware of Industry 4.0. It might therefore be concluded that Industry 4.0 is not having the impact which many have predicted and revolutionary ideas around the Fourth Industrial Revolution are somewhat detached from the reality shown in this research sample. Arguably then, what research is uncovering is more about evolution not revolution.

5.2.6 The Knowledge Questionnaire - Summary

The main conclusions to be drawn from this first section of the findings on knowledge from the research questionnaire are that the level of general awareness of Industry 4.0 and its associated technologies is arguably limited. Nonetheless, being that the questionnaire targeted the British automotive and manufacturing sectors who are arguably at the forefront of engaging with industrial innovations, the questions on knowledge revealed that a significant (portion) of the respondents 30% appear to be unaware of Industry 4.0. Moreover, this lack of awareness may be much wider as on 8 separate occasions the researcher was contacted by individuals from within his network who explained that they would not take the questionnaire as they had not heard of Industry 4.0. What is presented in these initial findings then may arguably understate or under-represent the actual lack of awareness within the UK automotive and manufacturing sectors. Despite the emergence of Industry 4.0 in Germany in 2011 (Kagermann et al., 2013) with its associated media hype, after ten years in the making Industry 4.0 is still unknown to a significant proportion within this questionnaire sample. Indeed, what can be drawn from initial section of findings is that Industry 4.0 does not look revolutionary at this point of time.

Returning to the questionnaire, when the respondents were asked about their level of understanding it was found that 13 have a limited or no understanding, 30 have a basic understanding and 10 claim to have an advanced and extensive understanding. When mining for further clarification through the descriptions, 8 descriptions have been highlighted as arguably more advanced responses where 13 of the respondents have suggested that Industry 4.0 has to do with integration. These findings then appear to corroborate and reinforce the idea that there is a small but distinct group of pioneers who seem to have a more detailed understanding of Industry 4.0 than the overwhelming majority.

A similar picture begins to emerge with regard to knowledge of technology insofar as the majority of the respondents have a basic to minimal level of knowledge and understanding across the technology groupings in question. However, what emerges from the findings is that a small but distinct number of respondents appear to have a more advanced level of understanding, which is again a common theme through the findings around knowledge. The findings across both areas of general and technological knowledge are arguably consistent insofar as they show that the level of knowledge is fragmented, with some ‘early’ pioneers pushing the knowledge boundaries more than most.

With regard to the final part of the questionnaire addressing the sources of Industry 4.0 information, personal research was identified as the only time that the respondents admitted to looking actively for information on the new technology. The other responses were arguably examples of how technology providers and the consultancy fraternity - along with the respondents' own companies - are pushing information to the respondents. Although this issue will be explored further in the interview section, it may be concluded for the moment that there is a significant level of media promotion and associated 'hype' with Industry 4.0. This excessive media attention is arguably causing the consultancy and technology providers to focus marketing efforts on engaging people within industry. It might be concluded that the revolutionary ideas first announced around a decade ago are largely fiction and what is emerging instead is the progressive evolution off the technology.

5.2.7 The Knowledge Interview Findings - an Introduction

The purpose of the knowledge interview section was to explore in further detail the level of knowledge on Industry 4.0 within the research sample, gauging the level of personal knowledge of each of the interviewees. The interview approach used open, semi-structured questions to find out what the interviewees thought Industry 4.0 was, before the focus shifted to measuring their knowledge by asking the interviewees to describe this phenomenon. After a first discussion to gauge their levels of personal awareness, the next section set out to explore with the interviewees the level of understanding within their relative organisations. As will be discussed, the objective here was to justify in discussion with the interviewees whether or not further understanding is required to assist in clarifying this phenomenon.

5.2.8 The Knowledge Interview

Of the twelve interviewees, only 3 suggested that they had an advanced understanding of Industry 4.0, while 2 admitted to having an average understanding, leaving 7 with a minimal understanding. These findings do corroborate what had been found by the questionnaire survey in terms of the awareness of Industry 4.0 and the ideas around early pioneers. Those interviewees who had a minimal understanding within the sample used words such as ‘minimal’, ‘novice’ and ‘amateur’ to describe their knowledge of Industry 4.0. Outlined below are five quotes from those respondents with a minimal understanding, who also discussed some of the reasons why this was the case. These responses included

- *‘Not packed altogether and understood.’* (RI:4)
- *‘I have my ideas on what it is, but I don’t know.’* (RI:6)
- *‘It needs someone to define what this is as there are so many different technologies associated all add confusion to the mix.’* (RI:5)
- *‘There's so many things that Industry Four touches on with things that we have been doing since Industry Three.’* (RI:2)
- *‘Very low and that by choice. If people would talk about what my needs are as a business, then I would be more interested in understanding more. I don’t think what I am being told is anything new it’s just repackaged in a different way.’* (RI:9)

The first of the descriptions given above is arguably very interesting as the way in which the interviewee responded does suggest a recognition that it is an aggregation of technologies which makes up Industry 4.0. As previously discussed, among some respondents these possibilities are aligned to the thinking behind the conceptual framework presented earlier within the thesis.

The second description might then suggest that the knowledge gained by the interviewee is self-attained and so validation is required either to confirm or refute their claim. The third and fourth descriptions confirm once again that some respondents have struggled to find their way through the maze of industrial technologies and have fallen short from achieving an understanding of the difference between today’s technologies and that of Industry 4.0. This level of confusion is supported from within the literature (Buer et al., 2018; Drath & Horch, 2014; Kolberg & Zühlke, 2015) along with the initial findings from the questionnaire research and literature.

The fifth and final description outlined above suggests a level of frustration from some of the interviewees, entailing that there is a push coming from somewhere which is beginning to switch some people off the idea of Industry 4.0. The statements made here suggest that interviewee RI:9 is making a conscious decision not to get involved, although his opinion also resembles some of the other respondents' general thoughts insofar as they believe that what is being sold is nothing new, merely repackaged under the heading of Industry 4.0. What might also be suggested from this statement is that while few technology providers are actually doing anything to understand the need of industry, a push marketing campaign has been involved.

Having a significant automotive network and holding a prominent position within the industry, KI:3 was adamant that the level of understanding gained around the subject of Industry 4.0 has only been an evolution of what he has learnt himself. During the interview, this individual sought validation for his thoughts on Industry 4.0, asking if they were correct. This request suggested a new idea might be introduced into the conceptual framework to confirm to the individual whether or not the interview process would be assisted by adding further clarification.

Although this suggestion will be covered further in the impact section of the thesis, KI:3 posted the following on his company's LinkedIn page in October 2021 which would be a recognition of confusions within the interviewees network

> *'Great articulation by Michael Bainbridge of Industry 4.0 and more importantly an understandable journey model. It's definitely worth contacting if you are one of the many organisations who need a map.'*

As highlighted previously, the description discussed by KI:1 perhaps makes sense in clarifying the revolutionary potential of Industry 4.0. Here it was suggested by him that

> *'There are the new technologies becoming available for people to use. When you put them all together or quite a lot of them together, It looks like a transformational change and that's why in in themselves, each technology may not look revolutionary because they are developments from existing capabilities.'*

The suggestion outlined by KI:1 does align with the previous ideas around the conceptual framework presented earlier within the thesis. It can hence be argued that what this statement does provide is a brief introduction to the differences between today's evolving technologies and what makes up Industry 4.0.

An additional question was then introduced to the interview process which asked the respondents to define the level of understanding within their individual organisations. The purpose of this additional question was not to confirm again – or validate further - that the general level of understanding is so low, but to determine whether or not there was any additional evidence to provide reasons why the level of understanding was so low. The results here do corroborate with the questionnaire finding that 30% were unaware of Industry 4.0. Interestingly, what was uncovered from many of the interviewees here is that some of the staff within their respective organisations do not want to understand Industry 4.0 as they are arguably intimidated by it. Instead, what can be drawn from the evidence suggested by the interviewees is that

- *'People are frightened of what it could mean.'* (RI:1)
- *'When I said scared as well, it's not necessarily people on the shop floor - I mean engineers.'* (RI:4)
- *'The older technicians do not want to know about it as I think some are a bit scared of it.'* (RI:3).

However, it might be said that this evidence only suggests a natural reaction in hinting at the fear of the unknown, which may be causing people from within the organisation to deliberately abdicate from anything focused upon Industry 4.0. Here, the research of Castillo et al., (2018) introduces six emotional stages of organisational change in a study broadly aligned with the seminal work of Elizabeth Kubler Ross (1926-2004). Castillo et al., (2018) discuss the different stages that the organisation goes through and the impact of technological change on personnel once it is upon them. Although variations on the theme exist, their model plots the different stages of affective change happening over time. For instance, the first emotional stage is shock which may be manifest in individuals not wanting to engage or perhaps complete abdication for engagement. In his own work as a consultant, the researcher has used this model for many years to assist in managing people through the various stages of change.

In an interesting discussion with a senior manager within an OEM, RI:1 admitted that he is one of those individuals who would struggle with adopting the technologies in questions. Following further probing, the same manager suggested he would find it difficult to adjust to such a radical change. Arguably such a conclusion is similar to what had previously been revealed in the correlation between technology acceptance and age profile. Perhaps these new advances in integrated and cloud-based systems will challenge some of the more traditional technical trades, causing a level of anxiety within certain areas of industry. However, such a conclusion does not necessarily correlate with the findings of the questionnaire.

The leaders and consultants of the automotive cluster are individuals engaged with wider spectrum of companies, entailing that the answers to the questions regarding the level of understanding within their network come as no surprise. Three interviewees RI:7, KI:2 and KI:3 suggested that

‘Within my network here in the northeast the level of understanding is 3-10 at best.’

‘It’s difficult to answer as its case by case as some have elements of it then other have different elements. I have yet to see anyone connect it together.’

‘Sporadic, but in general within the UK it’s very low.’

Arguably, the conclusion to draw here is that the level of understanding indicated by the three statements is very low. Here the suggested 3-10 level of understanding can provide a relative measure of the level of understanding within the individuals’ corresponding network. Again this evidence corroborates the finding that a third of the respondents were unaware of Industry 4.0. The elements of Industry 4.0 then outlined in the second statement suggest that pockets of technology evolution are occurring. Some respondents then appeared to connect technological development in general with what they believed to be Industry 4.0, but what makes Industry 4.0 different is its aggregated interconnectivity. Interviewee KI:3 suggests here that the small number of businesses with knowledge of elements of Industry 4.0 lie within the consultancy and engineering sector. Although there are other small pockets of knowledge within the network, the vast majority are characterised as ‘*unconsciously incompetent’.*

The third and final statement presented here validates the previous findings in confirming that the level of understanding is generally low within the interviewees' network. Here interviewee KI:2 suggests that although the UK automotive sector has one or two knowledge-leading businesses, many of the automakers are still trying to understand the movement, indicating that Industry 4.0 uptake is slow. The interviewee refers to three distinct types of organisations doing nothing about attaining knowledge in the hope that the Industry 4.0 issue will go away. There are then those organisations who are waiting for more developments, and finally those who already know about Industry 4.0 and are pushing the agenda. The interviewee also claimed that as it stands at the time of the interview, those organisations who know, recognise and implement the full effectiveness of Industry 4.0 are non-existent in the UK.

In posing the same question to the KI:1 regarding knowledge, his response was to evaluate the level of knowledge in terms of the number of articles written on the subject. Although such a measurement is insufficiently strong to answer the research questions in the UK automotive manufacturing sector, it suggests a general level of knowledge is available to industry. Previous research has determined that, since 2013, the number of publications surrounding Industry 4.0 has almost doubled year on year (Sestino et al., 2020). The evidence to support the views of the industry academic is indeed that the number of publications is increasing.

The picture beginning to emerge across both the questionnaire and the interview is that the level of knowledge and understanding is still relatively low. This lack is despite 10 years of diffusion, as the evidence suggests that the body of literature (Sestino et al., 2020) continues to grow and the marketing efforts of many consultative and technology bodies. A sort of triangulation might then be made between the questionnaire and interview findings and what KI:2 discussed which was the level knowledge within his network was 3-10. Although the findings corroborate with the original 30% of the total sample who have not heard of Industry 4.0, a small number of individuals appear to have emerged who seem to understand Industry 4.0 better than others. This is a common theme throughout questionnaire and the preliminary part of the interviews.

5.2.9 Describing Industry 4.0

Here the findings did not suggest a single prominent theme, but some interesting descriptions were still present in the interviews, including the following

'In a nutshell, industry for 4th revolution of technology is smart manufacturing & integration.' (RI:3)

Put differently, smart manufacturing aligned with integration is arguably a key aspect of this new industrial ecosystem composing Industry 4.0. In support of this aggregated system approach, one interviewee suggested

'It's the sharing of technology, which is the smarter adaptation of technology self learning, making it as lean as possible' (RI:6).

The sharing and interconnecting of platforms and the smarter adaption of artificial intelligence leading to a leaner operation are then seen as key elements within the afore-mentioned ecosystem. Both responses here are more closely linked to how Industry 4.0 is described and defined within this thesis as outlined within the literature review and within the conceptual framework section. Some other interviewees used terms such as *'advanced manufacturing', 'the future of manufacturing'* and the *'next level of manufacturing'* which are all arguably general terms. Other interviewees again mentioned that *'some are calling it an industrial revolution'*, using the terms *'revolution'* and *'It is a revolution'.* It might then be said that the use of terms such as 'industrial revolution' are examples of some respondents getting taken along with the hype. However, what may also be drawn from the findings is the conclusion again that there is clearly a small number of individuals who seem to have an advanced understanding of Industry 4.0.

An engineering director RI:2 operating within an OEM had arguably a more grounded opinion when describing the trends in question. The interviewee started by offering a description typical of the details generally is outlined above, but then suggested

'My knowledge comes from the business and the papers I read, and I don't necessarily share the same opinions as the literature and the rhetoric that's

coming out from it, to really push this forward. My mind hasn't really changed since Industry 4.0 became the buzzword that it is'. (RI:2)

'What is trying to be sold is something that we set out on a journey towards on our site since it started in 1995 with the PLC integration into an assembly process to allow us to access at track data'. (RI:2)

Similar to other individuals participating in this research, one of the perspectives given in the testimonies above is the interviewee beginning to become frustrated with the marketing efforts of the technology companies and other providers. This criticism of marketing efforts is a theme which has come up from within the questionnaire, and what has arguably been uncovered here is a technology push. This theme comes up in the statement given above but in other cases where people struggle to distinguish between today or even yesterday's technologies and that of Industry 4.0. This might demonstrate what the interviewee believes Industry 4.0 actually is and what the difference is between the two linked phenomena. These frustrations are also prevalent within the corresponding business media, which arguably leads to a stigma being attached to the term 'Industry 4.0'. Perhaps the cause of this media hype and marketing push now affecting people adversely is that much of the information given about Industry 4.0 is now seen as a collection of buzzwords.

Each of the respondents was asked if there was a need for further clarification around the subject. Here interviewees RI:2, RI:3 and RI:6 then gave the following details in response:

1. *'You know, even at plant leader level, even at supervisor level and even at team leader level.'*
2. *'Yeah, a need to understand it further but not like it's been done at the minute. It seems like there is always a hidden agenda with it.'*

3. *'Before you must invest all that time it's absolutely needed, and it's back to that If you don't really know what it is, how do you know what is going to give you.'*

Perhaps what can be taken from the first and the third statement given here is the need to get back to basics in educating industry on the fundamental elements of

Industry 4.0. From the evidence above, it would appear that what the respondents are asking for is a structured programme to assist people at all levels in terms of informing them about the benefits or just the role of the different organisational levels within the Industry 4.0 world. The third statement perhaps suggests a priority should be given to understanding the needs and outcomes of Industry 4.0 prior to implementation. These findings are in corroboration with what has been found within the questionnaire, as when discussing the skills requirements of the future the most prominent theme among the interviewees was the need to understand the basics. This statement thus suggests a hidden agenda giving rise to elements of mistrust, which is again a common theme within the research. Here the interviewee explained that there is a need to understand this phenomenon but a different approach needs to be taken to do so compared to what is being done at present.

At this stage, the proposition may be made that in terms of the questionnaire and interview findings, the levels of knowledge and general understanding do corroborate. Although the questionnaires demonstrate that there are those who seem to have a better understanding than others, the number of interviewees with more of an understanding is generally very small, and perhaps as small as 2 or 3 individuals. To contrast the two sub-groups then, while some respondents appeared to have a general understanding others switched off from the idea of Industry 4.0.

A similar finding arose when the interviews mined for a greater depth of knowledge about what the majority of respondents described as being 'not Industry 4.0'. Here, more probing questions were used during the interview to discuss the interviewees' depth of understanding. What was revealed here was that the level of understanding was again much lower than originally revealed. To summarise both the questionnaire and interview results then, the two do generally corroborate although it might be added that specific discussions taking place during the interviews revealed that the level of understanding was much lower than that uncovered during the questionnaire stage.

5.2.10 Knowledge Interviews Summary

What has been determined through the questionnaire-based investigation so far is that the level of awareness within the interviewees limited. However, one common thread suggests that a small number of individuals seem to have a much more advanced understanding of Industry 4.0 than the majority. These individuals seem to be the pioneers of Industry 4.0, which reflects a theme similar to what has been found within the questionnaires. This finding is also supported from within the network of KI:2 and KI:3, who describe the existence of pockets of knowledge but recognise that general understanding across their network is very low. These findings are also relevant at an organisational level where general understanding is low. What was suggested in the interviews is that three types of organisations exist within the UK: those who are doing nothing and hope this issue will go away; those who are waiting for more developments; and those who know and are pushing the agenda. The consultant (KI:2) interviewed here then validated these findings by stating that within his UK network, the organisations pushing the agenda are of a very limited number and of scope.

Another finding is that what people described in the interviews frequently conflicts with today's evolving technologies. One interviewee (RI:2) suggested that *'Industry 4.0 touches things that we have been doing since industry 3'* and as a business they are looking at *'cobot deployment, which for me is just a robot with sensors, cut the nonsense, but that's all it is'.* This piece of evidence arguably supports the conclusion that with regard to Industry 4.0, people have more ideas about evolution rather than revolution. These conflicting views also support the proposition that many industry stakeholders label any technological development occurring as Industry 4.0.

The interview and questionnaire has found ample evidence supporting the existence of this level of confusion. Here some of the marketing efforts of the technology providers and consultancy fraternity may well have mislead the interviewees. These evolving technological concepts are being repackaged and presented under the heading of Industry 4.0 which is arguably leading to confusion and frustration on the part of the interviewees. One additional knock-on effect of this confusion is why so many of the participants refer to a preponderance of buzzwords.

One of the variables that does need to be considered here is the age profile of the interviewees. It is arguable that in some cases the acceptance level for these evolving technologies is perhaps higher among the younger generation who are more accepting of Industry 4.0. However, the data overall indicates that this initial finding does not necessarily correlate with the age span, as confusion remains an important emerging theme.

One of the major themes emerging from this section on knowledge is that a lack of engagement is the reason for why knowledge is so limited. Arguably, fear is one of the key reasons for the frequent abdication of responsibility for knowledge. Such notions of fear are manifest in different ways, from fear of possibilities, fear of technicalities or fear about what the implications or outcomes of change could be.

5.2.11 Summary of Knowledge Findings

The findings within the questionnaire and interviews overall are very similar. The first significant finding that 30% of respondents had never heard of Industry 4.0 does set the scene for the overall level of knowledge. The picture beginning to emerge across both the questionaries and interviews is that the general level of understanding of Industry 4.0 is very limited. Both supply evidence supporting the claim that much confusion exists, and that people are struggling to understand the difference between today's technologies and those of Industry 4.0. A similar situation can be confirmed across the technology groupings insofar as the general level of knowledge is basic to limited. There is evidence of a number of reasons for this low level, one of which is the emerging nature of knowledge entailing that although Industry 4.0 is 10 years in the making many in this sample are just beginning to see Industry 4.0 emerge. Other possibilities explaining this lack of understanding are the marketing efforts and technology push coming from providers within the sector. Arguably, these misguided efforts involving repackaged technology solutions are causing confusion within the research sample. The reality that the buzzwords and technology phrases used have different meanings to different people all adds to this level of confusion. Of the research sample, one of the key informants who is closer to Industry 4.0 than most affirmed that only pockets of knowledge exist in his network and on a scale from 0-10, the level of knowledge out there is 3.

However, from a more positive perspective it is again evident throughout both the questionaries and interviews that a small number of individuals clearly know more than most about Industry 4.0. It is arguably too early to suggest that what is beginning to emerge is a trend towards a number of pioneers of Industry 4.0 who have taken knowledge development seriously. This advanced level of understanding is not only evident from within the questionnaire but validated in the descriptive part of the questionnaire and by the interviewees. A similar state of affairs was recognised within the technology section of the interviews insofar as there seems to be a small but distinct number of individuals who are ahead of the majority. The evidence there is that individuals are actively engaging in personal research and are using other sources of information to gain an improved understanding of Industry 4.0.

While the overall level of awareness is limited, clearly a small number of individuals seem to be taking Industry 4.0 seriously. Although knowledge take-up is slow in the sample of UK manufacturers, the evidence is that a core of knowledge or authority is beginning to emerge within British industry. Nonetheless, references to revolutionary development do seem to be overly strong in associating with what seems to be slowly evolving levels of knowledge of Industry 4.0.

5.3 Adoption Questionnaire - Introduction

5.3.1 Adoption Questionnaires

This section of the study seeks to understand the level of Industry 4.0 adoption within the sample of the UK automotive manufacturing industry by looking at the findings of the adoption survey. In the context of this research project, the term ‘adoption’ suggests that British companies are already using Industry 4.0, entailing that adoption has begun and there has been spending on the technologies which are then being commissioned, installed and in operation.

The survey process began by identifying which of the respondents had heard of Industry 4.0, and whether or not their companies are currently engaged with this phenomenon. In terms of the respondents who admitted they were already engaged, the further aim of research was then to determine how many of their companies have plans to focus on engagement with Industry 4.0. Identifying these plans might then determine whether or not organisations are taking the implementation of the new technology seriously, entailing that research will also be able to determine whether or not budgets have been allocated to this plan in findings which could then be used to determine the level of commitment demonstrated by the host organisation.

The first task of this section will be to determine whether or not the organisations know where to start upon their journey to Industry 4.0, which was ascertained by questioning their organisational readiness. Here the concept of readiness provides a starting point for determining whether or not the organisation was ready for change and where it would begin. The following section will thus determine the level of experience currently possessed by the respondents which will assist with the deployment of this technology.

Within the context of this research, ‘the measure of experience’ is an evaluation of the respondents as a whole in terms of how many have actively been involved with deployment efforts. The final section of this adoption survey will hence seek to understand what existing Industry 4.0 technologies are in place within the respondents’ organisations. Technology adoption timelines will also form part of the later section of this thesis, where these timelines will illustrate how the respondent’s organisations are focusing the investment of their time and resources in the coming 3 years.

5.3.2 Level of Company and Department Engagement

The initial question within the adoption question set identifies those 35 respondents in agreement that their organisations are engaged in some way or another in what they believe to be Industry 4.0. The sample size within the question set on adoption represents the total sample of 76 respondents (n=76). Within this context, the concept of engagement means that the respondents believe that their organisations are adopting Industry 4.0 technologies and principals to at least some extent. This may initially appear a positive response but given the highly limited level of understanding within the knowledge section it is actually questionable. However, the findings below do suggest considerable progress has been made towards Industry 4.0 in term of this sample survey, as 46% of the total respondents (n=76) suggested that they are in the process of adopting Industry 4.0.

The knowledge survey then revealed that 13 of the respondents have limited or no understanding of Industry 4.0, while 30 have a basic understanding. Here the respondents may be suggesting that what they believe to be elements of Industry 4.0 are already being implemented. Being that the overall level of knowledge was limited, one conclusion to draw from the open question section is that many of the respondents in the sample are actually describing today's evolving technologies. However, this is not really a question of the level of knowledge but more the inability to distinguish between the technologies of today and those of Industry 4.0. From another perspective then, 35 of the respondents admitted to being engaged in some way with industrial technologies and were able to provide specific responses about which of the departments in their organisation have been impacted, as highlighted in table 5.7 below.

Table 5.7 – Departments Impacted by Industry 4.0

Departments impacted	Total number of respondents
Production	34
Warehousing and Logistics	30
Supply Chain	27
Sales & Marketing	24

Research & Development	23

Arguably what is presented in table 5.7 above comes as no surprise, with 34 respondents suggesting that Industry 4.0 has impacted upon the production department within their organisations. After all, most of the survey respondents were people working in operations. Moreover, the reason why Industry 4.0 was originally developed is for its high impact across the production chain. Nonetheless, being that in the previous survey findings most of the respondent struggle to define Industry 4.0, then what some of the respondents are referring to here is arguably the potential of Industry 4.0 rather than its actual impact. The supporting evidence also suggests that many of the respondents struggled to distinguish between today's evolving technologies and that of Industry 4.0. Another alternative view is that the respondents are describing what they believe to be Industry 4.0 systems impacting upon their corresponding departments.

The next significant observable point is that 18 of the respondents suggested that they are not yet engaged with Industry 4.0 systems. However, it is difficult to determine at this point of the research why such a high percentages of UK manufacturers have not adopted the principles of Industry 4.0. What may then be evidenced from the research is that there is a general lack of understanding of Industry 4.0 from within the survey population. In this sense, perhaps the level of uncertainty might be one of the reasons why adoption is so low as people within UK manufacturing just don't understand Industry 4.0.

From the literature review conducted earlier in the study, it might also be suggested that several hurdles do exist within the adoption process. To take one example, Frank et al., (2019) suggest that the emerging new industrial stages and the associated digital technologies provide business with the challenge of how to implement and where to start their journey. Gillani et al., (2020) then present evidence from Zangiacomi et al., (2017) supporting this conclusion that the lack of understanding surrounding the complexities of implementing the technologies may lead to its failed execution. The problem of understanding how companies are adopting the technology then leads to questions about budget allocation as, arguably, without a budget the journey to Industry 4.0 cannot begin at all. These points will be discussed at a later point in the thesis.

Deeper investigation then established that a significant portion of the respondents who were not engaged with Industry 4.0 come from various automotive tier-1 businesses. This finding is again significant given that automotive companies generally lead the way in these industrial initiatives, reflecting back to the UK's lean manufacturing drive in the early 90's where certain members of the automotive industry were arguably early adopters.

Nonetheless, there are several variables to consider when discussing this technological adoption, one of which is the current state of the UK economy. Factors such as Covid-19, Brexit uncertainty and the ongoing microchip shortages could all be factors explaining why such a high number of businesses are not yet engaged in Industry 4.0. Given that the focus of such surveys is on the UK automotive manufacturing sectors, then the microchip concern is and continues to be the factor affecting these industries. This uncertainty might cause business leaders to rethink operational strategy and hence forestall any efforts to invest in Industry 4.0.

5.3.3 Planning for Industry 4.0

The planning section of the survey was designed in such a way as to determine whether or not the respondents' organisations view Industry 4.0 as a strategic initiative. This approach might also be used as an indicator of commitment on the part of the host organisation. The reason why this element is of importance within the context of the research is that without a strategic commitment, execution or implementation of Industry 4.0 may perhaps fail. Without these foundation blocks of strategic focus, which include the resources allocated, the time given for deployment and the budgets developed and allocated, successful implementation may still be unachievable. Within this context, the foundation blocks then provide the basic resources required to begin the implementation of these new technologies. This plan also supports a readiness assessment able to provide an overview of the current state of operations, along with short, medium and long terms goals which support the 'building needs pillar' schema outlined within the conceptual framework.

It was also revealed in this part of the interview survey that 14 respondents believe their organisations to have a plan to implement this new technology. Again, this was a finding that might seem quite positive insofar in indicating that their organisational leaders are taking positive steps to engage with Industry 4.0. It might then be argued that if organisational leaders have spent valuable time developing a plan, then perhaps this is a demonstration of their seriousness and commitment to Industry 4.0. These 14 respondents, or 18% where (n=76), are arguably what Rogers (1962) calls 'early adopters' or the pioneers, or enthusiasts. In support of these positive steps forward demonstrated by a small number of respondents, 16 among them then suggested that they have a budget allocated for Industry 4.0. The suggestion here is that with a plan developed and a budget allocated, there was a clear demonstration within this sector of commitment to the Industry 4.0 cause.

Subsequently, one plain conclusion to draw here is that Industry 4.0 does already exist within the UK automotive and manufacturing companies. However, despite being ten years in the making along with all the accompanying media hype, the findings of the research sample reveal Industry 4.0 still to be very much in its early stages of adoption. Here, certain researchers suggest that adoption is to be measured by the number of people who adopt the new idea over a period of time (Rogers et al., 2014, p. 206). In this sense, the ideas around fourth industrial revolution are perhaps somewhat overambitious at present, with evolution rather than revolution being a more appropriate term to describe the emergence of Industry 4.0. However, what can be taken from the research is that a high technology strategy is beginning to evolve within the automotive and manufacturing industry. Clearly something is beginning to emerge, and the evidence does suggest that along with the relatively small numbers of take-up, what has perhaps been revealed are the 'early adopters' of Industry 4.0.

Interestingly, Rogers et al., (2016) do identify 'variables' determining the rate of adoption. These variables are the perceived attributes of innovation, decisions on innovation, communication channels, the nature of the social system and the extent that change agents are operative (Rogers et al., 2014, p. 206). One of the key perceived attributes to which Rogers et al., (2016) refer is 'innovation complexity'. From the knowledge findings in this section of the research, it can then be established that widespread understanding of Industry 4.0 is basic to minimal. It may also be argued that Industry 4.0 is a complex phenomenon. Therefore, linkages can be made to the work of Rogers et al., (2016) on adoption and to what has been found from within the research, not only from a diffusion perspective but in understanding some of the reasons behind the complexity.

From a slightly more negative perspective, the results revealed that 20 respondents either did not know or could not say whether or not their company has a strategic implementation plan. On a basic level, without a plan the journey to Industry 4.0 may be fraught with difficulties, and without a clear picture of what the future should be accurate allocation of resources would become almost impossible. This lack of clear direction could then lead to a lack of strategic engagement with the business needs for Industry 4.0 on the part of the corresponding teams or departments. Implementation might then be fragmented and ad-hoc, leading to a lack of tangible return on investment, being that alignment to strategic business performance indicators may well be missing. Implementation resources would then be wasted on activities failing to have an impact upon the overall performance, as a business manifestly wasting time and resources.

Overall then those respondents unaware of a strategic plan were suggesting that, as a whole, it was highly likely that their company did not have a plan. The target population for the survey were individuals most likely to be involved in managing Industry 4.0 within their relative companies. Given the limited level of knowledge established earlier in the research, these findings appear to corroborate with existing findings.

In extension then, the findings suggest that for most of the organisations represented in this questionnaire, deployment efforts have a higher potential to fail given that two major enablers are excluded. With no strategic plan and no allocated budget, the question should then be posed of how deployment efforts would possibly succeed. It is highly likely that this lack of organisational commitment will lead to small, isolated deployments made locally, but with minimal impact and being difficult to quantify. With no strategic focus and no direction, existing capex budgets might instead be used which will set limitations on the technology selection and arguably lead to attempts by business to push technology rather than establish a strategic pull coming from their business needs. Perhaps from an alternative viewpoint then, it is the lack of budget allocation that explains why business leaders do not understand what Industry 4.0 can do for their operations.

In summarising the first two sections on company/department engagement and planning for Industry 4.0, one conclusion to draw is that the level of diffusion is limited. What has been uncovered are signs of early adopters or pioneers. It might be suggested that the work of Rogers et al., (2016) on adoption variables does begin to bring clarity to some of the reasons why there has been a lack of diffusion of Industry 4.0. This distinct group of early adopters forms a common theme throughout the knowledge and adoption findings. These early adopters already have plans in place and budgets allocated which clearly demonstrate commitment, engagement and intent. The picture then beginning to emerge and supported by the evidence is that Industry 4.0 does exist within the sample of the research and is so emerging in the UK automotive and manufacturing industry. Perhaps the idea of industrial revolution is just an overly strong term to describe Industry 4.0, whereas evolution would be a more appropriate term.

5.3.4 Understanding How to Engage with Industry 4.0

The suggestion has been made that once organisational leaders decide upon Industry 4.0 as a strategic objective, then a form of business assessment would be required. As discussed in the literature review, organisational readiness is used to determine, among other things, whether or the organisation is ready and set up for change. Organisational readiness then serves as measure of an organisation's current capability to take advantage of Industry 4.0 and its associated technologies (Hizam-Hanafiah et al., 2020).

Many different models of evaluation then surround the various themes involved here. To give one example, Hizam, Hanafiah et al., (2020) have reviewed 97 peer reviewed academic journals to find 30 different readiness models with 158 unique dimensions. Depending upon which manufacturing sector the organisations operate, the transition to Industry 4.0 is arguably a demanding task. Readiness assessments can hence be used to determine items such as technology infrastructure, the operations set-up and many other dimensions arguably required to establish the current state of the implementation operation.

The concept of readiness hence seeks to determine what infrastructures are currently in existence and what would need to come into existence in an organisation for a smooth transition to Industry 4.0. Without evaluation then, it would almost be impossible to determine whether or not the organisation is ready for the change, meaning that without assessment of the current operational state of a particular organisation, improvements could be ad hoc with a lack of measures of the return on investment becoming difficult to quantify. Organisational readiness can then provide business leaders with the resource requirements required to assist with the transition to Industry 4.0.

The results from this part of the survey found that only 5 respondents are engaged in Industry 4.0, which equates to 7% where (n=76). These respondents were alone in suggesting that a readiness assessment had taken place in their organisation, leaving 93% suggesting that they do not know or had said ‘no’ to a readiness assessment. These findings are surprising given the fact that the target audience for the survey are individuals who are likely to be involved with organisational readiness assessments.

Moreover, there is an argument that if these individuals do not know whether or not a readiness assessment has taken place, then it is likely that it has not occurred at all. If no readiness assessment has taken place, then it may be argued that the adoption process does not have a starting point where the current state of implementation operations can be considered to determine whether or not the current systems or infrastructure are capable of making the transition. Along with all the afore-mentioned technical downfalls, the lack of readiness might demonstrate that business leaders are falling short in understanding what it takes to start their technology journey.

Looking at the previous findings on plan and budget allocation to observe the small number of respondents believing that a readiness plan or process has taken place, the thought that comes to mind is that the emerging picture of Industry 4.0 is more complex. Although in some cases plans are in place and budgets have been allocated, only 7% of respondents have decided that a readiness assessment is essential to the start of the adoption journey. Such shortcoming may suggest a lack of commitment and this evidence does seem correlate with the lack of general understanding within the knowledge section of this thesis.

Another variable to consider was demonstrated in the survey results. The finding here is that although plans and budgets are in place, the respondents are not yet at the requisite stage of readiness. Readiness is arguably the next stage of deployment, and this negative finding supports the previous findings on the slowness in the rate of diffusion. However, from a more positive view a small number of organisations are taking the adoption of Industry 4.0 serious and what can be taken from these findings from the evidence on view is a level of competency from within the sample. These pioneers are leading the way in knowledge and adoption of Industry 4.0 within a sample of the UK automotive and manufacturing industry.

When asked about the level of experience of Industry 4.0, four respondents then suggested they have an advanced and extensive understanding of Industry 4.0. Again, this small but consistent number of respondents are arguably the pioneers of Industry 4.0. It may then be argued, but not yet confirmed, that the five respondents who have engaged with readiness are those who have more experience in Industry 4.0 as readiness in whatever the form is perhaps a prerequisite for successful deployment. The other findings revealed that of the respondents, 14 have basic experience, 14 have limited experience and 3 had no experience at all. These findings about basic to limited experience might also corroborate with the evidence of organisational readiness as they suggest that the respondents genuinely do not know where to start this new journey of industry, and this despite having a plan and a budget allocated.

In summary, these findings are aligned with the work of Frank et al., (2019) who suggest that the emerging digital technologies provide business with a challenge around how to implement them and where to start their transitional journey. Gillani et al., (2020) then present research conducted by Zangiacomi et al., (2017) which also supports these findings, concluding that the lack of understanding surrounding the complexities of implementing the technologies can lead to its failed execution in organisations.

In summary, the finding suggests that 7% of the respondents are taking engagement efforts seriously as they have engaged in assessing whether or not their organisation is ready for change. However, such a small number would suggest the emerging picture beginning to emerge is that the adoption of Industry 4.0 is much more complex. Although plans and budgets are in place in some cases, only 7% of respondents have engaged in readiness. Perhaps one of the reasons for this lack of readiness is that the respondents just do not know where to start with deployment efforts. There is also the idea that the respondent's companies are just not there yet in terms of readiness, entailing that an organisational assessment is the next step of engagement. The research findings also revealed that just four of the leaders had advanced and extensive experience of Industry 4.0.

5.3.5 Existing Technological Adoption and their Expected Timeline

The following questions outlined within this section asked the respondents to identify which technologies are currently in existence within their organisations, with the objective of demonstrating which of those organisations have already committed to the Industry 4.0 journey. The intention of these questions was to gauge the readiness of organisations to determine a starting point for the technology adoption on top of the resources they had already committed to Industry 4.0. In fact, the survey questions were structured to provide an overview of which technologies were aligned to the groupings developed through the conceptual framework. The results (n=76) named the top five technologies currently implemented within the respondent's companies: cloud computing (30%); smart manufacturing technologies (26%); smart working (21%); smart products (21%); and analytics (20%).

What has been revealed in the findings is that 30% of the respondents believed in one way or another that cloud computing technology is currently in place within their business. While it was difficult to determine precisely what the respondents were generally suggesting, the assumption was that they were referring to cloud-based IT systems rather that the specific use of cloud technology within the context of manufacturing. Again, the ambiguity revealed the lack of general understanding outlined previously in this research.

What is of particular significance to this question set was that only one respondent suggested that cyber physical systems are in existence in their company. To appreciate why this response is of significance means going back to the origins of Industry 4.0, particularly the work of Kagermann et al., (2013) who suggest that Industry 4.0 was the “fourth stage of the industrial revolution based on cyber physical systems”. These authors suggest that the whole idea of Industry 4.0 is based upon cyber physical system yet in this research, only one respondent suggested that their organisation had some form of cyber physical system in place.

What can be taken from these findings and what has been uncovered within the previous sections is the general consensus that there are some ‘early adopters’ of Industry 4.0. However, progress has been very limited and perhaps more limited again in consideration that key technologies such as cyber physical systems are in existence within only one company. Perhaps what these findings have demonstrated is also supported in Kusiak’s (2018) conclusion that in terms of evolving technologies, those such as big data and analytics have evolved from today’s industrial data systems. As discussed earlier in the thesis the internet of things has evolved from the world wide web, while the front-end technology grouping consisting of smart technologies could then be said to constitute the technologies of today. Such findings might support earlier ideas that Industry 4.0 is rather evolutionary than revolutionary. What is in place within this sample of UK automotive and manufacturing companies appears to support these ideas.

Table 5.8 underlines how quickly the respondents suggest that their individual companies will adopt the technologies associated with Industry 4.0. The findings presented here show that 6 respondents think that cyber physical systems will be adopted in years 2 and 3. Although the views of Kagermann et al., (2013) suggest that cyber physical system will be a major element of Industry 4.0, this did not seem to be a priority of many within the sample population here. If the viewpoint of these authors were to be considered, then if the respondents do not see cyber physical systems as a strategic priority, what they are engaging with is arguably something different and unconnected from today’s evolving technologies.

To recall, the table below outlines which technologies and technological groupings the respondents suggest that their business will focus upon in the coming 3 years. Clearly the respondents are suggesting that cloud systems of some form will be the priority for the coming year. As previously highlighted, the reference here is to a cloud-based system rather than using a cloud within the context of manufacturing. From the base technology grouping outlined within the conceptual framework cloud then, the internet of things, big data and analytics are mentioned as the focus of technology implementation within the coming years.

Table 5.8: Suggested timeline for technology implementation

Year 1	Year 2	Year 3
Cloud 15	Cloud 8	Analytics 7
Smart Working 14	Smart Products 8	Cyber Physical Systems 6
Internet of Things 12	Internet of Things 7	Smart Supply Chain 6
Smart Products 12	Cyber Physical System 6	Smart Manufacturing 6
Smart Supply Chain 12	Smart Working 5	Big Data 4
Smart Manufacturing 10	Smart Supply Chain 5	Internet of Things 3
Analytics 10	Smart Manufacturing 4	Smart Products 2
Big Data 9	Analytics 4	Smart Working 2

In summary, the results from this section on technology adoption highlight that the top 5 technologies currently in place within the respondent's organisations are cloud computing, smart manufacturing technologies, smart working, smart products, and analytics. It may also be suggested that these are technologies are evolving technologies. The significant finding here is that cyber physical systems as the technology which, according to Kagermann et al., (2013) underpins Industry 4.0 is only in existent within one organisation. Supporting the claim of this slow rate of diffusion when asking the respondents about technology implementation timeline, 6 respondents out of the 35 suggest that cyber physical systems will be implemented in years 2 and 3.

This finding supports the previous idea that Industry 4.0 revolutionary rhetoric is at present evolutionary technology development. The table above could thus be used as a guide to determine what technologies the respondents are looking to implement in the coming three years. However, considering the level of knowledge of industry from the majority of respondents is so low, then what is arguably being presented here is a set of opinions on the technology time-line.

5.3.6 Adoption Questionnaire - Summary

The survey results show that 35% or 46% respondents (n=76) suggest that their organisations are adopting with what they believe to be Industry 4.0. This finding points towards considerable progress having been made towards adopting Industry 4.0. However, the results of the knowledge survey and interviews previous outlined also suggest that if the respondents cannot describe Industry 4.0 with any accuracy, then they are unlikely to be able to justify its implementation within their organisations. What they may instead be suggesting here is that they are engaging with what they believe to be Industry 4.0 technologies.

It was also revealed that 34 of the 35 respondents suggested Industry 4.0 has impacted the production department within their organisations, which is arguably no surprise given its industrial origins. Moreover, 18 of the respondents suggested that they are not yet engaged with Industry 4.0 systems. At this point of the research, it is difficult to determine why such a high percentages of UK manufacturers have not adopted the principles of Industry 4.0. Nonetheless, from a knowledge perspective there could be several explanations for this failure to adopt, including a general lack of understanding, the current level of uncertainty and the general complexities of implementing the technologies. Other factors to consider are the current state of the UK economy with Covid-19, Brexit uncertainty and the ongoing microchip shortages all being factors explaining why such a high number of businesses are not yet engaged. This uncertainty might cause business leaders to rethink operational strategy and hence stop any efforts to invest in Industry 4.0.

What was also revealed the survey is that 14 respondents suggest their organisations have a plan to implement this new technology. This is a positive finding insofar as their organisational leaders are taking positive steps to engage with Industry 4.0. In support of these positive steps forward demonstrated by small number of respondents, 16 respondents then suggested that they have a budget allocated for Industry 4.0. Perhaps what Rogers (1962) calls ‘early adopters’ or the pioneers or enthusiasts are beginning to emerge within this sample, which arguably confirms that elements of Industry 4.0 do exist within the sample of UK automotive and manufacturing companies. However, despite being 10 years in the making with all the corresponding media hype, Industry 4.0 is still very much in its early stages of adoption within the sample. Individual ideas about fourth industrial revolution are perhaps somewhat overambitious at present in terms of their practical implications, entailing that evolution rather than revolution maybe a more appropriate term to describe Industry 4.0.

Returning to the survey, of the 34 who are engaged with smart technology transition, 20 of the respondents did not know if they had said no to a strategic implementation plan, while 21 explained that no budget has been allocated to its deployment. It may be argued here that deployment efforts present a higher potential for failure given that two major enablers are excluded; that is, with no strategic plan and no allocated budget then how can deployment efforts succeed? Perhaps from a viewpoint of their ability to demonstrate a level of competency, this lack of budget allocation indicates that business leaders do not understand Industry 4.0.

Again, organisational readiness is another area which falls into ambiguity in terms of the respondents’ perspectives. Here, only 5 respondents (equating to 7%) suggested that a readiness assessment has taken place, leaving 93% of those questioned suggesting that they did not know about a readiness assessment or had said no to one. Given the realities of the professional role of the respondents these findings are surprising. That is to say, if a readiness assessment has not taken place in their organisations, then the adoption may not constitute a starting point enabling the infrastructure of the current systems to make the transition. Alongside the aforementioned technical downfalls of ill-prepared organisation, this lack of readiness arguably demonstrates that business leaders don’t understand what it takes to start their new technology journey, leaving further negative suggestion of their level of competency. The results also revealed that 4 of the leaners admitted that they had advanced and extensive experience of Industry

4.0. Although a small number, this finding does suggest that some pioneers are leading with the way with Industry 4.0.

Finally, the results of the section on technology adoption have highlighted that the top five technologies currently in place within the respondent's organisations are cloud computing, smart manufacturing technologies, smart working, smart products and analytics. One of the more significant findings was that cyber physical systems are only in existence within one organisation, although according to Kagermann et al., (2013) this technology underpins Industry 4.0. Nonetheless, the survey did provide some idea of what technologies the respondent believe will be implemented within the coming three years and here, interestingly, cyber physical systems only appears in years 2 and 3.

5.3.7 Adoption Interview - Introduction

The purpose of this section is to explore ideas around adoption to determine how a sample of the UK automotive and manufacturing industry are currently adopting the principles of Industry 4.0. The initial question on adoption within this semi-structured question set were intended to explore how the interviewees' organisation are currently adopting and engaging with Industry 4.0. This exploration was performed by first asking the interviewees how each of their relative organisations were engaging with Industry 4.0.

The next section of this thesis discusses the challenges and barriers which the interviewees have encountered through the engagement process. The final section of the thesis then explores the ideas about whether or not the interviewees believe Industry 4.0 is necessary in today's competitive marketplace.

5.3.8 Level of Engagement

The interview with an American-owned UK manufacturer established that his organisation has invested heavily in Industry 4.0. Here interviewee RI2 suggested that the organisation had broken down the technologies into individuals 'buckets', listed as *"augmented and virtual reality, cyber security, additive manufacturing,* *secure reliable network, standard core systems, manufacturing data hub and the industrial internet of things".* Each of these buckets had a global lead, while at site level each site had a person responsible for delivering the outcome of that specific bucket road map. When the interviewee was asked if he was connecting with the inbound and outbound logistics, his reply was

"Just manufacturing and IT other than the AMR. The autonomous mobile robot is effectively just an AGV, however, rather than following a wire guide or painted line on the floor, it follows coordinates and its self-learned environment."

What can be drawn from the findings here is that the leadership emerging from within the organisation seems to be taking a strategic approach to efforts to implement Industry 4.0. Particular decisions on budget allocation, along with structuring decisions on how the company's global operations have structured the deployment buckets and allocated local resources then seem to indicate that Industry 4.0 is a business priority.

Another conclusion to draw is that the addition of a manufacturing 'bucket' is nothing new but the fact that business has made these technological choices demonstrates that some diagnostics have taken place. This mode of diagnostic has hence uncovered seven technologies that the business will focus upon as a strategic priority. Arguably, what is presented here is a positive example of an organisation which has adopted Industry 4.0 and is currently engaging with it.

Even when such a positive example of adoption is given, there are still some uncertainties around the execution. It is notable for instance that this global initiative has not taken into consideration the requirements of the local sites. Within this context, the requirements of the local sites encompass the current set-up of the infrastructure and the product manufactured, which was confirmed by interviewee RI2. The two interviewees who work for this company, RI2 and RI6, both suggested that the most of their staff do not understand Industry 4.0. One senior engineer (RI6) then suggested that although his company is pushing on with some form of technology deployment, he still does not understand Industry 4.0.

From the evidence presented within these findings then, it might be concluded that a widespread people engagement strategy is not how this business has chosen to deploy this technology. Questions might then be raised as to whether a people engagement approach is needed for this high technology strategy, while others have argued that this approach moves away from their original ideas on Industry 4.0 (Kagermann et al., 2013, p. 8).

A discussion on infrastructure is covered later within the research findings presented here. For the moment, what is presented above is a clear example of a company taking positive engagement steps. However, evidence has also been found to the contrary as, on two separate occasions, the interviewees RI9 and RI4 suggested that

'We're not engaged at all with anything that I would class the next development in technology. We have the capability to get feedback from sensor from some of our equipment but that been with us for some time. People are at the heart of my small business.' (R19)

'Our company is still playing catch back on the maintenance basics where we're nowhere near'. (R14)

The opinions given above arguably come of little surprise, given that the research findings have presented the reality of so many organisations not being engaged with this phenomenon, reflecting on what is being mis-sold to the interviewees in terms of media hype and even revolutionary marketing rhetoric. It is also unsurprising that some individuals are starting to switch off to the idea of this phenomenon. The first statement from R19 introduces another interesting dimension as to why some people may not be engaged, suggesting that this statement expresses a degree of concern. That is, the interviewee expresses the belief that the cause-and-effect relationship of Industry 4.0 is where technology replaces people, which is arguably not an uncommon reaction given the level of uncertainty around the subject. Perhaps the interviewee is not seeking a technology manufacturing base and sees far more value in a people-based business rather than a high technology footprint.

The second quotation given above from participant R19 is then quite pragmatic in comparison. The implementation of a high technology strategy by a company still struggling to do day-to-day business might be a reality check for many. It is something of a surprise that other interviewees did not suggest this to be the case, although the researcher’s own experience justifies this view. Many businesses struggle with daily operations and seek to add an extra layer of complexity when standard maintenance routines and preventative routines are often missed. However, for many operational leaders the focus is more likely to be on deriving the best use out of the today’s equipment rather than adopting something which has the potential to add more complexity to the system.

In terms of the scale of technology implementation, most of the interviewees are positioned just a little above a position of doing nothing at all. Four of the interviewees suggested that their organisations have someone in place who is pushing for the implementation of Industry 4.0, but they have yet to see much in the way of engagement. One of the interviewees positioned within a tier 1 manufacturer as the site’s lean lead then provided an example of how their organisation is engaging with the phenomenon.

Each month this organisation sends out a spreadsheet which asks the lean manufacturing leads of the global sites to write up any improvements involving the implementation of technology. The example given was of a standard software update forming part of their preventive maintenance regime. This software update was already planned as a maintenance task, but the company suggested that they were going to classify its implementation as Industry 4.0. The spreadsheet being updated is standard practice which nonetheless seems to be recognised centrally in the organisation as an Industry 4.0 achievement. However, one of the other interviewees RI8 who fall within this section of engagement suggested that it is

‘Something we're just scratching the surface with - we have someone who is sort of driving this but it’s not at the top of the business priority list.’ (R18)

The first example given above might be said to demonstrate that the priority for the organisation is to be seen to be doing something about the Industry 4.0 agenda. Although justification for this approach is difficult to determine without further analysis, past records do provide examples of when the share price has risen through similar improvement efforts (https://www.sigmapro.co.uk/measuring-return-oninvestment-with-lean-six-sigma, no date).

Certainly, these improvements might be an outcome of the direct efforts put in place by organisation but at this point it is unclear why such issues are arising. This extreme example is an anomaly although some of the opinions and reflections revealed in the findings and discussed here expresses a similar theme. In this example, the organisation has been using the allocated Industry 4.0 budget to fix everyday concerns within the business, although this contradicts what another of the interviewees mentioned in terms of Industry 4.0 being used to solve everyday problems. Again, the conclusion to draw here is that Industry 4.0 is still in its early days in the evolution of the phenomenon in the UK industry, entailing that his lack of knowledge around the general subject - along with leaders not knowing where to start the journey - is causing an extended timeline in the rate of diffusion. These ideas on early implementation and development are supported by one of the more senior interviewees RI1 who suggest that the *'movement is being born and not fully developed'.* The individual not only supports the ideas around early adoption, but the idea that it is not yet fully developed could be a factor causing the slowness in adoption.

The view from the consultant KI2 here on the individuals within his network suggests that the gulf between those who are engaging and those who are not will become wider. The interviewee suggests that

'My real worry is that big companies are going to get bigger and smaller companies going smaller.' (KI2)

'OK, let's say we're going to see digital titans, digital giants, digital dragons, and we're just going to see other companies fading away. The adoption lower down is just very, very low.' (KI2)

The evidence given above does to some extent correlate with the overall findings within this section of the research. The respondent organisations making more advanced efforts to engage is a large OEM and is relatively advanced with its implementation efforts. Meanwhile, the organisations at the opposite end of the deployment efforts are small companies classified as small to medium-size enterprises (SMEs). From this perspective, the findings do correlate. However, the organisations in which the rest of the interviewees belong are classified as large organisation and here the findings do not suggest that the larger organisations are all engaging across this sample. Indeed, there are many more variables to consider before any such correlation can be justified. The view given by KI3 about the automotive cluster and why the network is not engaging suggests that *'very few of SME's have conquered the tech puzzle. Many have focused on lean and failed.'*

Interviewee K13 may appear to tell similar story to those given above, insofar as some of the smaller enterprises are struggling to engage with Industry 4.0. But here the interviewee does bring a slightly different context to the discussion around engagement, by discussing Industry 4.0 as an evolving organisational journey. The interviewee suggests that what has been witnessed as exemplary instances of technology adoption is where companies have maximised the opportunity with their people first. Maximising the opportunity with people means implementing a process with minimal nonvalue added and wasteful activity while maximising the value-added work. This is arguably a fairly utopian view of lean manufacturing first suggested by the former Toyota executive Taiichi Ohno (Ohno, 1988, p. 1x). Ohno (1988) suggests that what made Toyota different was this removal of waste and non-value adding activity to the order timeline.

What the interviewee might be suggesting here is that investment in technology adoption is easier if a system of lean is operating within the host business. There might well be a valid argument for applying this logic, as building a foundation of lean can make sense in giving implementation efforts something upon which they can build. The question then becomes one of whether or not the company can be said to have achieved everything it can before investing money in a high technology strategy.

This line of questioning aligns with the previous thinking outlined earlier in the thesis about getting industry 3.0 right before implementation of 4.0. In fact, these findings do suggest that a prerequisite for successful adoption of Industry 4.0 is having a system to build it upon. Certainly, the implications of this school of thinking are of significance, suggesting that a level of lean maturity is needed for the successful deployment of Industry 4.0. Another conclusion to draw is that the rate of diffusion is much longer than was first suggested by Kagermann et al., (2013).

Generally, the conclusion that can be drawn from this initial section on adoption both from the questionnaire and interview perspective is that the evidence from within the sample of UK automotive and general manufacturing organisations points to the adoption of Industry 4.0 occurring. A small number of organisations have indeed made the decision to plan, budget and start implementation efforts. however misguided they believe Industry 4.0 to be. Similar to what was found within the questionnaire section on adoption, a small number of pioneers could also be said to be leading the way with Industry 4.0. However, such a finding relates only to a small number of organisation where similarities can be draw from the work on Rogers (1962) and 'early adopters'. Interestingly an alternative dimension has been uncovered from within this interview section in respect to organisational types. Contributing to the knowledge section, KI:1 then suggested

'Three distinct types of organisations doing nothing about knowledge in the hope that this issue will go away. There and then those who are waiting for more developments and those who already know about Industry 4.0 and are pushing the agenda'. (KI:1)

Arguably, a third organisational type has been uncovered here, as the organisation wants to be seen to be doing something regarding Industry 4.0. However, in reality, engagement efforts are very different.

5.3.9 Barriers to Industry 4.0 Implementation

The following section explores the concept of blockers to implementation. The objective here is to explore whether or not anything specific has been stopping the organisations from adopting Industry 4.0. Within the interview context, the original thoughts around these questions were aimed at understanding what blockers - or barriers - the interviewees had encountered during their implementation of Industry 4.0. Not surprisingly, one of these blocker factors was the cost, which is something a small number of interviewees suggested would be a barrier to the implementation. A more technical theme was then discussed by a small number of interviewees who suggested that shortcomings in cyber security and the IT infrastructure might inhibit successful implementation.

Another interesting finding was then revealed from within the research: the idea of procrastination. On two separate occasions in reference to different companies the interviewees suggested there had been discussions around Industry 4.0, but nothing had proceeded. One of the individuals (RI5) suggested that it was something which 'corporate' would want to be seen doing, when the reality was very different. The individual suggested that the lack of time and lack of conviction, resources and leadership would bring about the same failing which, elsewhere in industry, is still being seen daily with the implementation of lean.

These notions about the capability on the part of leadership have been covered in previous sections of the research while more detail is given below. Interviewee (RI3) suggested a level of reality that may be similar for many organisations as this level of bureaucracy has also been uncovered at corporate level. Two other interviewees, RI3 and RI5, then discussed corporate planning as a barrier to implementation, suggesting the following:

'I have started to develop the business plan for this, but I struggle to get the buy-in from Japan to help me create this industrial strategy.' (RI3)

'Unless it's something which is being pushed by corporate and a budget is developed, we won't do anything in the UK.' (RI5)

The first of the two above statements might suggest that despite a push coming from one of their sites in the UK, the corporations in question are not pushing Industry 4.0 as a strategic initiative. Without that corporate buy-in, implementation may be hampered if not blocked. Not only would the capital needed for implementation be lacking but interconnectivity with the other global plants could be blocked, leaving implementation efforts arguably localised and firms unable to achieve the potential benefits of the aggregated, interconnected aspect of Industry 4.0. As highlighted within the adoption questionnaire, perhaps what this evidence demonstrates is that the adoption of Industry 4.0 is much more complex, especially when the organisations are multinational.

The second statement given above by RI5 appears to suggest a similar outcome might be achieved as to the first, with the difference being that the UK operation would not start the implementation efforts without first getting corporate approval. Arguably, these levels of bureaucracy are barriers to the implementation of

Industry 4.0. These barriers could then prove a significant challenge within the UK automotive sector, given that the majority of the OEM's are foreign-owned and overall diffusion would be slow irrespective of the scale of any efforts of local implementation. As discussed within the questionnaire in accordance with the testimonies of this research sample, all of the above gives reasons why after 10 years of Industry 4.0 its overall diffusion is somewhat limited.

Only one major theme comes these findings in relation to personnel or the workers who make up these companies. The findings given in Figure 6.1 below present the actual words of the staff involved and their frequency in indicating the potential barriers to implementation. As a sub-theme, a lack of understanding of Industry 4.0 has clearly been suggested by most interviewees. These findings are aligned with those of the previous research, both from the literature and from empirical findings of this research, although it might be suggested that these constitute barriers rather than blockers because a programme of learning and development could be used to overcome these uncertainties.

Interestingly, the findings addressing management buy-in bring a different context to the discussion. As a reminder, all the interviewees within this sample are organisational leaders within their own right. The positions they hold within their organisations give them responsibility for leading a team of people at a senior level. The suggestion here is that the problem as they see it is not with operational leadership but with the strategic leadership within their respective companies. As highlighted within the previous discussions, it may be suggested that although some of these figures have recognising leadership capability as a barrier, the importance of this element is being underestimated for all the reasons previously highlighted. If the issues are with strategic leadership, then perhaps this finding might be classed as a potential barrier to organisational efforts to implement Industry 4.0.

Figure 5.4: Barriers as suggested by interviewees

Two of the responses came from the interviewees RI5 and RI8 regarding leadership buy-in:

'Leadership, as our leaders just don't want to change. I think they like it the way it is.' (RI5)

'Leadership capability, as they do not want to go outside their comfort zone, so they won't change.' (RI8)

It is arguable that statements such as *'We have always done it this way'* or *'People won't change'* are familiar aspects of everyday industrial life. Moreover, the interviewee's suggestions are far from uncommon statements, being heard during most change programmes with which the researcher has been involved through his career. It could also be highlighted that the statements are the consequence of a culture which does not recognise innovation or even people's contribution. Might these statements then be thought of as characteristics of resistance? While the statements above might well constitute aspects of organisational culture, or indeed resistance characteristics, it may be better to claim that it is what business leaders do about them which will prove the more critical issue.

The perspective offered by interviewee KI1 might then be said to introduce a more general approach to barriers or blockers to implementation. This interviewee suggested that *'any technology implementation can have a number of barriers, not blockers but barriers.'* Here the interviewee emphasised that the skills requirements and usability around the user interface and capital investment may be two clear barriers to overcome. Interestingly, certain ideas around the usability of technology were further discussed by the interviewee here in the suggestion that companies might struggle to understand how to get the best out of the selection of the aggregated technologies, further suggesting that one significant barrier could be *'getting the technologies to do what we want.'*

It might be said that what is being presented in the above findings is the valid suggestion that different technologies might be brought together, many of which could run on different operating platforms to provide a significant challenge. As today's industrial technologies evolve at an accelerating rate, having a system which interconnects them all surely presents a challenge for the implementing business. The automotive cluster lead does recognise this to be a problem for UK manufacturers because it stands in contrast to what one of the respondents witnessed during his visit to a German plant where the systems, tooling and technologies were all interconnected to one system.

A similar concern was also recognised by RI2, who suggested that although the company are taking their implementation efforts seriously to suggest one size fits all is a weakness in tactical deployment. Here the interviewee suggested that in the UK and Americas the control systems are different, which would inhibit how the selected technologies are deployed and then eventually controlled. As suggested above, barriers rather than blockers still remain to implementation. Examples then of how these challenges could be overcome is through the use of cloud computing services such as SaaS (software as a service), PaaS (platform as a service) and IaaS (infrastructure as a service), which are all layered system used to assist with platform integration.

In summary, the picture beginning to emerge at this stage in the research is that there are signs of 'early adoption' from within the sample. While some plans and budgets are in place, it is evidently a small number of pioneers who are leading the way with Industry 4.0. What has been revealed in the findings is a different organisational type in firms that want to be seen to be doing something when, in reality, adoption efforts are very different.

This section on barriers has revealed that although local level plans are in place, in some cases company adoption overall is much more complex with the challenges of procrastination and corporate bureaucracy faced by some. The survey results have also revealed that poor leadership, knowledge, cost and technical complexities are all additional challenges faced by industry. Indeed, some of the reasons why the level of adoption appeared limited according to the questionnaire and interviews findings have come out of this section on barriers.

As discussed during the questionnaire section, the findings of Rogers et al., (2014) on the 'variables in the rate of adoption' are aligned to those revealed within these two sections on adoption. Considering these findings, it is evident that what has been identified within the previous empirical work as the "fourth Industrial revolution" is not occurring frequently. Instead, what has been uncovered is the evolving implementation of industrial technology.

5.3.10 Competition

What can be determined from the question as to whether or not Industry 4.0 is needed for a competitive edge to be maintained? Several interesting findings can be developed here. The main theme was one of necessity, especially for organisations competing in challenging markets. Interestingly, although some initial reactions have highlighted a level of scepticism and arguably fear around Industry 4.0, the overarching view is that it will be an essential tool for organisations to utilise to remain competitive. One interviewee explained that for the automotive manufacturers to remain competitive they must be globally connected. He further explained that Chinese, Korean and Asian brands are now becoming more prominent within European car sales, pointing out that the Korean-made Kia Sportage is now a prominent top 10 product bought within UK monthly car sales, which was unthinkable not so long ago for UK consumers. He then suggested that the general population within Asia are more accepting of change than they are within the west, while many countries in Asia understand the need and benefits of Industry 4.0 to a far greater extent than many companies in the West, particularly in the UK.

This recognition of the threat of the US and Asia was the original energy behind this high technology industrial strategy first presented in the Hanover fair of 2011

(Kagermann et al., 2013). Here Germany's Industry 4.0 working party claimed that utilising a high technology strategy to create competitive differentiator would allow the high wage economy of Germany to compete in a global marketplace (Kagermann et al., 2013; Alcácer and Cruz-Machado, 2019). Hence, in support of the Asia competition suggested above in the first nine months of 2021, Kia was the 10th bestselling brand in Europe outperforming all brands with a growth rate of 24.5% https://www.best-selling-cars.com/europe/2021-q3-europe-best-sellingcar-manufacturers-and-brands.

Figure 5.5 – Top 10 Cars Sold in the UK (SMMT)

BEST SELLERS

	DECEMBER 2021			YEAR TO DATE	
1	Tesla Model 3	9,612	1	Vauxhall Corsa	40,914
2	MINI	4,625	2	Tesla Model 3	34,783
3	Vauxhall Corsa	2,608	3	MINI	31,792
4	Nissan Juke	2,270	4	Mercedes-Benz A-Class	30,710
5	Nissan Qashqai	2,122	5	Volkswagen Polo	30,634
6	Ford Puma	1,827	6	Volkswagen Golf	30,240
7	Vauxhall Mokka	1,821	7	Nissan Qashqai	29,922
8	Volvo XC40	1,755	8	Ford Puma	28,697
9	Peugeot 2008	1,672	9	Kia Sportage	27,611
10	Nissan Leaf	1,578	10	Toyota Yaris	27,415

Vehicle registration data (SMMT, 2022)

Certainly, it is remarkable that an Asian brand has outgrown all the other brands in Europe over the last nine months of 2021, which was one of the predictions. The UK data published from the SMMT confirms that Kia Sportage was the 9th bestselling car in the UK in 2021. That the second place in the top 10 UK cars sold is now Tesla then supports the evidence for a US brand threat. It may also be argued that the threat to British manufacturing highlighted 10 years ago is now slowly coming to fruition. The competition highlighted will threaten OEM's, as the pressures of falling costs and rising performance will eventually lead to pressure on tier 1 and 2 manufacturers.

The view then offered from interviewee KI1 regarding competition was that within the UK, automotive companies are constantly competing both for domestic sales and their products going overseas. If your competition is becoming more efficient by utilising these technologies, then competitive edge will be lost in a relatively short period of time. As KI1 puts it, '*Industry 4.0 is therefore essential for UK manufacturers and its supply chain to remain competitive'.* From the evidence given above regarding competition, the claims made by this interviewee are in direct correlation with the findings. In short, these competitive pressures appear to be growing more now than ever before, not only in Asia and the US but due to electrification.

In a contrasting theme RI2, who has invested heavily in Industry 4.0, responded as such:

‘That’s a good question as any improvements that we get within the business which help with operational efficiencies will be an element which can assist with our competitiveness but is it a necessity I can’t answer that as I just don’t know.’ (RI2)

It is arguable that the slowness of diffusion does make it difficult for individuals to quantify progress if no concrete outcomes have been achieved during implementation. Then, if quantification has not yet been achieved, how can implementation be determined as a necessity for competition? What has instead been revealed in the above discussions is that even though this business has invested significantly, the desired outcomes have still not yet been achieved. Arguably, these findings are of significance in terms of pointing to an organisation further progressed in diffusion than any other within this research. Yet a senior manager fundamentally cannot answer whether or not Industry 4.0 is a necessity for competition. Going back to the reason why this high technology strategy was first developed in Germany to keep ahead of the completion (Kagermann et al., 2013), it may be suggested that at this point for the research the slow diffusion prevents any confirmation of whether or not Industry 4.0 is a competitive differentiator.

One of the final themes to consider emerged from two of the interviewees who suggest that the recent industrial turbulence will put off any effective implementation of Industry 4.0. One suggested that there *‘seems to be a lot of investment needed and given the current climate I am not sure it will happen here quickly*.’ Arguably what is being described here is a short-term view of where investments are to be cut to assist the management of this industrial turbulence. Whether this is the right or wrong decision for an organisation will depend upon several variables, one of which may be its cash and risk position. Nonetheless, this is an interesting discovery insofar as it may be seen as another barrier for implementation.

To summarise this short section, most of the interviewees recognised the need for implementation due to increased levels of competition. As predicted, competition within the sector is indeed increasing in Europe (Kagermann et al., 2013; Alcácer & Cruz-Machado, 2019), yet the level of adoption remains strikingly low for the majority within the UK despite its launch a decade ago. From the conclusions of the previous research, it can be confirmed that there are indeed some definite barriers to implementation. However, the overall findings suggest that it is the lack of understanding - of not knowing where to start - as well as corporate politics and all the other barriers surrounding the staff of these organisations which are stopping people from engaging with Industry 4.0. Another barrier to implementation which was suggested, and highlighted earlier within the findings, was the *'current climate'*, or perhaps a better description would be the current industrial instability. These general findings are in alignment with the work of Rogers et al., (2014) on 'variables in innovation diffusion.'

5.3.11 Adoption Interview - Summary

Overall, what can be concluded from the research findings is that there are indeed some small signs of engagement with Industry 4.0 from within the sample. The evidence presented here suggests that a small number of the interviewees' organisations have already constructed a strategic initiative to engage positively with Industry 4.0. The contrasting view is one where the organisations are just not ready for the change and, in some cases, do not want to adopt this high technology strategy. However, most of the interview positions were between both conjectures with the interviewees suggesting that their organisations are in some way engaged with what they believe to be Industry 4.0 even if they are still early on in their journey.

The interviewees also named prerequisites for successful deployment, entailing that their organisations may need to have some specifics in place prior to implementation. One of the suggestions made is that there needs some form of stability within operations prior to implementation of Industry 4.0. One interviewee suggested here that there is a need to fix the problems being faced operationally today. Building upon this idea of prerequisites is the finding that engagement may also depend upon the level of lean maturity. Arguably, this pragmatic view can make a lot of sense to certain organisations at their stage of implementation.

One interviewee also provided evidence that some of their organisations just want to be seen to be doing something concrete. Similar notions were also mentioned by KI3, suggested that this perspective could be more widespread than just within this sample of the research. It might be argued that this finding is significant, yet it comes as little surprise to the researcher. A small number of interviewees also suggested that if organisational leaders do not adopt them then the gulf between the haves and have nots will become much wider, making it more difficult for the late majority of laggards (Rogers, 2010) to keep up with the competition.

Interestingly, in terms of barriers to implementation, two major themes were identified with several corresponding sub-themes. The main themes were procrastination and/or politics on a local and corporate level and the role of employees as stakeholders. Arguably, procrastination is linked to the previous discussion in this section concerning how organisational leaders want to be seen as doing something toward Industry 4.0 and digital/smart manufacturing. It may also be suggested that the role of the leader should not be underestimated when discussing deployment efforts.

One of the more significant findings within this section concerned an organisation who have invested heavily in engaging with Industry 4.0. It has been established that this organisation is further progressed in the diffusion than any other within the sample. Despite this financial investment and the rate of diffusion, interviewee RI2 nonetheless suggested that they did not know whether or not engagement was needed for competition. One finding emerging here is that at the time of the interview, the effect of adoption had still not been confirmed.

5.3.12 Adoption Summary

The picture beginning to emerge based upon the evidence within the research is that there are indeed signs of early adoption of Industry 4.0 from within the sample. However, the evidence from within both the questionnaires and interviews has also attested to the existence of organisations that have been slow to engage with this phenomenon and others who hope it will just go away.

At the same time, there is a small but distinct number of pioneers who are evolving their engagement with Industry 4.0, and who are preparing both strategically and financially for its adoption. There was also evidence to suggest a smaller number of innovators who are taking adoption seriously enough to constitute a form of organisational readiness. This small group of pioneers is a common theme from both the findings within knowledge and adoption. They are individual who have plans in place and budgets allocated, both of which suggest that some actors are taking the adoption of Industry 4.0 serious.

However, while Industry 4.0 is clearly beginning to emerge within the sample, the overall level of adoption is still relatively low. It may be concluded that after over 10 years in the making, the rate of diffusion remains slow and what has been witnessed is much more evolutionary than revolutionary. Moreover, it may be concluded that the adoption of Industry 4.0 is not happening at the pace that many of the technology suppliers and consultancies would first have wished, and that there are a number of reasons for this. The level of general understanding is low, complexity is high, and the organisational politics and procrastination are all factors slowing the diffusion of Industry 4.0 which, in terms of the sample, are all 'variables' aligned to the findings of Rogers et al., (2014).

Another conclusion is the significance of cyber physical systems which, according to Kagermann et al., (2013), underpins Industry 4.0 but, according to the sample, are not going to arrive in British industry any time soon. In this sense, although Industry 4.0 is beginning to emerge, the rate of diffusion is still slow and the evidence suggests that it has the potential to remain that way for some time more.

5.4 Impact Questionnaire - Introduction

The purpose of the impact questionnaire was to stage a detailed investigation into the impact upon the business of the research participants since the implementation of Industry 4.0. Any exploration of the level of impact began at the most basic level by asking the respondents if they believe Industry 4.0 has impacted upon their organisation in any way. The following section will then determine which areas within the business have been affected and whether or not this impact can be quantified through any key performance indicators.

The impact upon the business as a whole was the next focus, asking the respondents to determine the impact of implementing Industry 4.0. The last part of this section will ask the respondents whether or not, in their opinion, implementing Industry 4.0 has been a worthwhile activity or otherwise.

In terms of finishing off this impact section, the next step will be to determine whether or not the respondents see Industry 4.0 as a necessity to remain competitive in today's competitive manufacturing environment. In the last section of the findings looking at impact then, the objective was to establish whether or not any of the respondent's organisations have engaged in a programme of learning and development. Here the questionnaire sought to determine whether or not active engagement in a process of learning and development would assist with the transition to Industry 4.0 and then demonstrate a commitment on the part of the host organisation. Finally, the respondents were asked what they believed the skills requirements of the future would be.

The following section will outline the effect that Industry 4.0 has on employment within the respondents' host companies.

5.4.1 Has Industry 4.0 Impacted Your Business?

The results of the initial impact question produced the key finding that 31 (n=76) of the respondents suggest their organisation has been impacted in some way by Industry 4.0. This finding does corroborate with the adoption questionnaire findings of 35 respondents who have in some way adopted Industry 4.0. While 35 of the respondents were engaged, 31 have also been seeing an impact which does appear to be a positive finding. Overall, from within the sample of 76 respondents 31 are already seeing the impact, equating to 41% of the total sample. This is arguably a significant result given the level of conjecture throughout the findings surrounding the suspicion that the respondents had a limited level of understanding. It might be claimed that what the respondents are witnessing is the impact of technology in general rather than specific technological impact within the context of Industry 4.0.

From one perspective, what is being demonstrated here arguably supports the argument that a level of confusion exists among the respondents regarding their understanding of Industry 4.0 which, as a conclusion, is supported from within the previous findings. From a slightly more negative viewpoint, 22 respondents then suggested that Industry 4.0 has not impacted their business. This outcome is no surprise given the levels of confusion and misunderstanding present, as well as the perception that the diffusion of Industry 4.0 is in its infancy and that people do not know where to start in engaging with it.

5.4.2 Areas Impacted

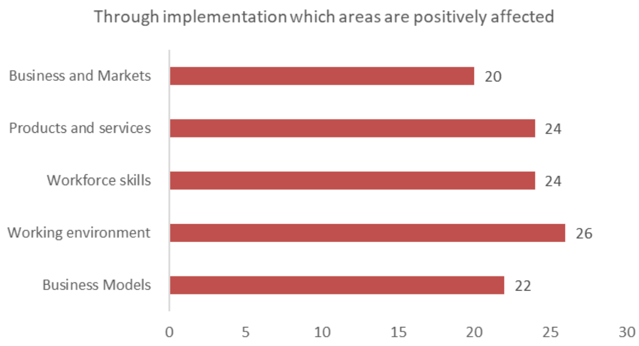
The data given in Figure 5.6 below indicates that as a positive response across all the areas impacted, the working environment comes out the highest with 26 respondents. As previously discussed, these findings are of no surprise given that most of the questionnaire respondents are operationally focused. What can also be observed is that on average 30% of the respondents (n=76) suggest that Industry 4.0 could affect all the areas outlined in the figure, which would suggest a level of recognition that Industry 4.0 has a wider application than just manufacturing alone.

Asking the respondents why these areas have been affected has led to three major themes: implications for the wider business; impact on productivity; and effect on workforce development. Two respondents then suggested that

'Smart technology should have a positive impact on the working environment and the products and services given to the customers, stakeholders and investors should also benefit from a smarter workforce'.

'It should drive a closer working relationship with our customers and suppliers so that we are managing across a full supply chain rather than a single location. It is likely that we will move towards more flexible manufacturing processes capable of several generations of manufacture'.

Figure 5.6: Areas affected by Industry 4.0



The positives that can be drawn from this evidence suggest that the respondents do seem to appreciate the implications for Industry 4.0 in a much wider sense than merely production-related activities. This integrated end-to-end value chain is arguably what makes Industry 4.0 different from what is seen in today's industrial settings. Such narratives also suggest a level of competency from within the respondent's sample in terms of their overall understanding.

However, the use of the words *'should'* and *'likely'* may suggest future tense implications rather than the current state of play. The structure of the questions was directed towards the current impact of Industry 4.0, but what is presented within these questionnaire findings is the potential rather than the actual applications of the technology. This finding is a common theme throughout the empirical investigation, as arguably what many of the respondents are suggesting is the potential of Industry 4.0 rather than what has occurred or is occurring in terms of technology.

Moreover, in terms of the productivity theme, one respondent suggested that

‘Cost and efficiency, quicker production, better quality, streamlining and removing waste and improved quality cost and delivery.’

The above statement is what might be anticipated when discussing shop-floor-based productivity improvements, meaning that the improvements mentioned are typical outcomes which would come from improvements in workplace productivity. Another interesting response on the productivity theme was

‘Having Industry 4.0, information from all areas of the business will lead to improvements in all areas.’

As already discussed, the choice of words here in the future tense suggest that this respondent is predicting future applications within their organisations rather than describing what is currently happening. What is under discussion are possibilities rather than actual impact. However, what can be taken from this statement is the recognition that Industry 4.0 is just not based purely within manufacturing and impact will be seen in all areas of the business.

The final theme drawn from the impact questionnaire is workforce development. Here the respondents suggested that

‘Improved technology and a need to upskill staff, people development, smarter workforce’.

‘Need to upskill employees’.

Interestingly, what the respondents may be suggesting here is that rather than job losses as some predict (Frey & Osborne, 2013; Kusiak, 2018), what might be most impacted upon are the skills of the workforce. This subject will be covered in detail in a later section looking at the other impact findings.

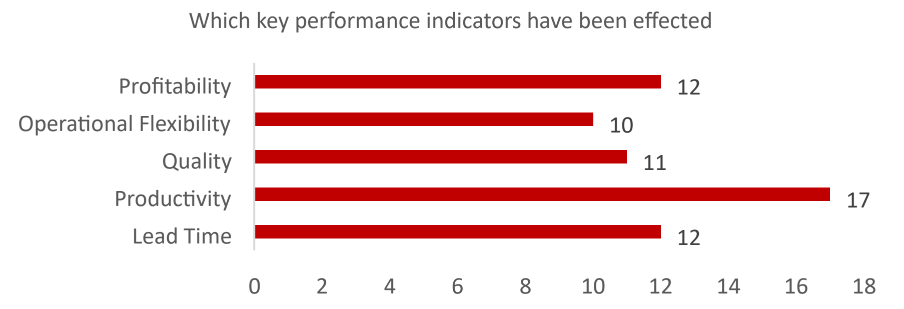
The picture beginning to emerge regarding impact is mostly a positive one as from the 35 respondents who are adopting Industry 4.0, 31 perceived what they regard to be a positive impact. Overall, the picture is that 41% of the total sample (n=76) are suggesting Industry 4.0 has impacted their business. In terms of other findings, it was also revealed that on average 30% of the respondents (n=76) suggest that Industry 4.0 has positively affected the areas highlighted in figure 5.10. The indication here is that some do recognise Industry 4.0 to have a wider application than just manufacturing. However, the use of verbs in the future and conditional tenses suggest that the respondents are predicting what could happen rather than what has already occurred. Although the overall picture is positive there is still some conjecture. Hence, the perception of the areas impacted by Industry 4.0 has led to the isolation of three major themes: implications for the wider business; impact on productivity; and effect on workforce development.

5.4.3 Impact on Key Performance Indicators

This question was designed to enable the respondents to quantify their assessment of the impact of Industry 4.0 by citing their key performance indicators. The rationale behind this part of the questionnaire was hence to derive further validation of the impact findings taken from the previous sections covered in the questionnaire.

According to the frequency chart given below, what appears consistent is the recognition that Industry 4.0 has impacted productivity or is currently doing so within the respondent's organisations. One perspective to consider is that after production-related areas at the start of the implementation efforts, Industry 4.0 has the potential to impact all areas of production in the future. Nonetheless, the first outcome to be seen has been the impact on productivity.

Figure 5.7: Key Performance Indicators impacted



To engage with these findings further, it is crucial to recognise the three key themes emerged from the findings when the respondents were asked to justify their claims: firstly, improved decision-making; secondly, cost and efficiency; and finally, the impact on all areas of the business. The focus on benefits and the value of real-time decision-making was then encompassed in statements such as

‘More visual live data has allowed us to operate more dynamically.’

‘Real-time decision-making.’

‘Better understanding of machine downtime.’
‘Reliability centred maintenance.’

‘Live monitored data for each process.’

The first two statements here suggest that the application of a live visual data system and real-time decisions have enabled the respondent to perceive a certain level of impact throughout current processes. The need for a dynamic and flexible system has already been discussed in detail within the literature review when defining the concept of Industry 4.0. In discussion of the analogy with an ecosystem, it was also highlighted that dynamic flexibility is one of the key factors in Industry 4.0. It might hence be suggested that what has been revealed within the sample is how elements of Industry 4.0 are starting to emerge within UK manufacturing and automotive.

This finding is corroborated in the previous section which concluded that a small group of people are taking implementation efforts seriously. In addition, such outcomes are what some were predicting would transpire, especially around data system and decision-making. These pioneers or early adopters seem to be leading the way in Industry 4.0 deployment from within the sample. However, the other statements arguably represent nothing more than what today’s data management systems should already be providing within today’s industrial setting.

To move on, looking at the respondents who discussed cost and efficiency in their responses, a sample of their statements are presented and discussed in this section

‘All areas can become leaner and more profitable with the implementation Industry 4.0.’

The perspective presented here comes as little surprise given that the purpose of Industry 4.0 is to improve overall business and operational performance. However, what is arguably being described in the future tense are the implications of Industry 4.0. Another common theme arose when a respondent recognised that the potential impact could be wider than just production again. This broader understanding of Industry 4.0 was also recognised by another respondent who suggested

‘The implementation of the Industry 4.0 aims to improve and make processes efficient which is covered by all the KPI's listed above and they are all interrelated.’

This respondent recognised how key performance indicators interact with each other, entailing that what affects one might indeed impact upon all of them. This statement might then suggest that the respondent recognises that Industry 4.0 does not reflect a narrow, isolated approach but has the potential to impact performance across the whole business.

Another useful example from the sample was where one of the respondents recognised that Industry 4.0 has the potential to influence his entire organisation for the better:

‘Industry 4.0, Smart & Digital Manufacturing must affect every aspect of the enterprise to succeed.’

The statement entails the respondent recognises that Industry 4.0 is required not only impact on isolated production activities, as that the interconnection can be spread across the whole organisation. This statement might then demonstrate a level of competency in terms of his understanding of Industry 4.0.

Interestingly, one respondent suggested that

Projects carried out so far have impacted all areas. Improvements made in production have benefits throughout the organisation and ultimately help all departments.

The statement presented here is one of the few times that the respondents mentioned how an actual Industry 4.0 project has impacted their business positively. While other respondents use language in the future tense, the statement above corroborates with previous findings suggesting the actual implementation of Industry 4.0. What can then be concluded from these statements is that at least one of the respondents had seen the positive impact upon their business of what they believe to be Industry 4.0 projects. The conclusion might then be drawn that although it is early days, a small number of the respondents from within the sample are beginning to see a clear impact of the technology which is aligned to what many have predicted.

In summary, from this short section on key performance indicators there is evidence that Industry 4.0 has impacted business in some areas, particularly in terms of productivity measures. Other evidence has been provided by the respondents who recognised that the impact of Industry 4.0 will be much wider than simply production-related areas.

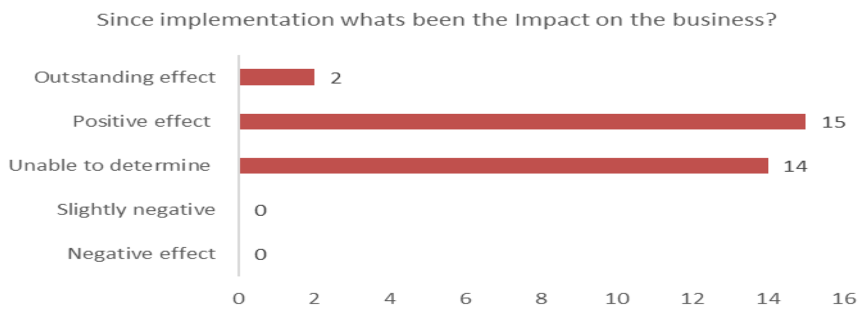
However, when trying to validate the scale of impact through additional questions to the participants, the results are somewhat sketchy. Within this impact section there clear signs of Industry 4.0 beginning to emerge, which is a common theme through the research, but what has also been revealed is that some participants are talking about potential rather than actual impact. These findings then corroborate with the previous findings that a small number of Industry 4.0 pioneers understand the concept better than most. Moreover, these are the actors who are actually adopting Industry 4.0 technologies and so witnessing their impact within their relative organisations.

5.4.4 Level of Impact on Business

The rationale behind this question was to explore in further detail the level of impact within the respondent's organisations. This section began by asking the respondents what the impact has been upon their host businesses. The second part of the question then sought to explore and quantify the level of impact. The final part of this impact section then discussed whether or not the respondents believed that implementation had been a worthwhile activity.

The frequency table below then outlines the effect that Industry 4.0 has had on the respondents' host businesses. Here, 15 respondents suggested a positive impact while two suggested that the technology has had an outstanding effect. In terms of findings, what was revealed here is positive insofar as 22% of the sample (n=76) suggested a positive and outstanding impact.

Figure 5.8: Impact upon the business



Again, what the research has revealed is common throughout both knowledge and adoption that a small but distinct number of respondents confirm that Industry 4.0 implementation has impacted their organisations positively. These pioneers or early adopters have put some effort into understanding and engaging with Industry 4.0 and are now seeing their efforts rewarded through organisational impact.

When the respondents were asked why the impact was positive and outstanding, two replied by suggesting that

'Access to accurate on-time performance data influences decision-making by ensuring better productivity from the operational side of the business combined with the visibility of areas to focus on improving.'

'Easier access to real time data and more rapid response / decision-making.'

As previously discussed, the real-time exchange of data and consistent decision-making are both key elements of Industry 4.0 and its ecosystem. It may therefore be suggested that what these two respondents have witnessed in terms of impact is indeed characteristic of what some are describing as Industry 4.0 benefits.

Two respondents suggested that

'*We have supported some headcount activities as well demonstrating quality improvements.'*

‘Removing human influence with smarter automated systems where necessary.’

While quality improvement is again a potential key outcome of Industry 4.0, this idea of ‘*headcount activities’* and *‘removing human influence’* may be viewed as an inhibitor to staff engagement and successful implementation. Employment levels are covered in detail later in this section of the findings. For the moment, depending upon what ‘*headcount activities’* and *‘removing human influence* means, these ideas could open the debate around technological unemployment. Here the findings confirmed are also supported from within the literature (Frey & Osborne, 2013; Kusiak, 2018; Pereira & Romero, 2017; Schröder, 2016), as headcount changes have occurred as a consequence of implementing what the respondent suggests is Industry 4.0.

Within the sample then, 14 respondents were unable to determine whether or not Industry 4.0 has impacted their business. Given the emerging nature of Industry 4.0 and its slow rate of diffusion, it is actually surprise that the number is not higher than only 14. Here the respondents suggested the following:

‘*Too early, too little at this point to determine impact.’*
‘Too early and can’t determine impact at this point.’

‘*Disruption to manufacturing over last 12-14 months makes it difficult to assess impact’.*

Arguably, the way in which these opinions are expressed reveals that although the respondent organisations are on their journey to Industry 4.0, the level of impact is difficult to determine at this point. These observations correlate to the findings of the adoption section which argue that some adoption has occurred but only in its initial stages while diffusion has remained slow. According to the findings of the adoption section, the lack of organisational readiness, plan and budget might all be factors hindering impact. These findings provide more evidence to suggest for the moment Industry 4.0 that is evolution not revolution.

One additional factor to consider which was revealed in both the knowledge and adoption sections is that the respondents may not know where to start with the deployment of Industry 4.0. What is arguably misguided advice from technology providers and consultants also needs to be considered as barriers to implementation. Hence, 14 of the 31 respondents suggested that Industry 4.0 has impacted their business but were unable to ascertain how it had done so. Considering all the afore-mentioned factors, this finding comes as little surprise. Moreover, with so many of the ‘Industry 4.0 building blocks’ missing, many of the current efforts to realise an impact may fail as many have not started their journey in the correct way.

When the respondents were asked whether or not the implementation of Industry 4.0 has been a worthwhile activity, 11 suggested they are unable to decide whether or not implementation had been valuable, which is something of a surprise. Going on what has been uncovered from the findings, it is a surprise that this percentage is not higher given the lack of general understanding, strategic focus and readiness along with the lack of budget allocation.

However, the major finding within this last section on impact is a positive response as 20 respondents, which is 26% of the total sample (n=76), suggested that implementation of Industry 4.0 has been a worthwhile activity. Given all the concerns previously discussed, along with the slow rate of diffusion, this is arguably a significant finding because those pioneers choosing to engage with Industry 4.0 are beginning to realise some of the initial benefits. Not only that, but the time and investment which has been allocated to the initial implementation has been a worthwhile activity for the respondents’ businesses. Due to the slow rate of diffusion what the respondents are witnessing is merely a small portion of the potential of Industry 4.0, while the significance of this industrial movement is yet to be realised.

When the respondents were asked why, only one recurring theme came from the findings. This theme was competition, regarding which the respondents offered the following:

‘A need to retain competitiveness.’

‘It will give companies global competitiveness.’

‘Keep up with other OEMs.’

It is apparent from the sample then that some respondents feared been left behind and saw Industry 4.0 as a competitive differentiator. The subject of competition will be covered in more detail in a later section of these findings, but for the moment, when asked if implementation has been worthwhile one of the respondents suggested:

‘But only where it is required. The cost of data is a new commodity... not every piece of data needs recording and reporting.’

One interpretation of this statement is that the respondent recognised the need to understand business requirements prior to the implementation of the technology. It is the tendency of outside parties to push the technology rather than understand business needs which has been a common theme throughout this thesis, both empirically and in terms of what has been drawn from the literature. What this respondent confirmed arguably correlates with the rest of the findings insofar as business requirements need to be understood rather than technology being pushed for the sake of it.

In summary, the picture emerging within this section on impact is positive for a small number of respondents. The influence of Industry 4.0 within these respondent’s host organisations is indeed beginning to occur and has been outstanding, positive and worthwhile. Around 20-25% of the total sample (n=76) took their implementation efforts seriously and the impact of the technology is beginning to register for them. What a small number of respondents described are clearly technologies more associated with Industry 4.0 and specifically concerned with autonomous decision-making. It might also be suggested that the real benefits of Industry 4.0 are yet to be realised. As one respondent attested, this transition to Industry 4.0 is just beginning to emerge.

From a slightly more negative perspective, some conjecture also arose from within the findings. As an example, what some of the respondents are describing is the potential of Industry 4.0 rather than the actual impact. It was apparent that some of the respondents struggle to distinguish between today’s technologies and that of Industry 4.0, which is a common theme throughout the research. Hence, despite their implementation efforts certain respondents were unable to determine whether or not Industry 4.0 had benefitted their business in any way.

5.4.5 Competition

As highlighted in the section above, several of the respondents within the sample suggested that implementation efforts have been worthwhile as they can be used as a competitive differentiator. In order to mine for further understanding, the respondents were then asked: ‘Is implementing the Industry 4.0 technologies needed for your organisations competitiveness?’

Table 5.9: Is Industry 4.0 needed for competitiveness?

Essential	8
Highly Important	13
Important	9
Slightly Important	1
Not important	0

The conclusions to be drawn from the above findings is that according to the views of the respondents within the sample, implementing Industry 4.0 is a vital factor in enabling organisations to remain competitive. Interestingly, during the knowledge questionnaire, many of the respondents demonstrated a basic understanding of Industry 4.0, yet a significant percentage believed that it is a necessity to remain competitive. As previously discussed, perhaps one of the reasons for this finding was the respondents’ fear of their organisations becoming left-behind business, which is unsurprising given the push coming from the consultancies and technology providers along with the associated media hype. As outlined previously, the use of business social media such as LinkedIn and online trade magazines may be triggers causing a potential ‘bandwagon’ of Industry 4.0 followers. Along with the original ideas about its revolutionary potential, such triggers might explain why many of the respondents within the sample believe Industry 4.0 is vital to remaining competitive.

These ideas about trepidation, caution and fear in organisations are echoed in a sample of the respondents. When asked why, the respondents offered three main themes about Industry 4.0: efforts to improve efficiency; the fear of been left behind; and Industry 4.0 as an enabler for organisational growth. As efficiency efforts have been covered within most sections of the research findings, the following section will focus upon the fear of being left behind and organisational growth. To take first the theme of fear of been left behind, some of the respondents suggested the following:

'Those who have digitally transformed will be more flexible and adaptable to the market, and thus be more competitive and successful than those who haven't'.

'Other plants will be more efficient, cheaper and have higher quality standards, overtaking plants that are not engaged in Industry 4.0'.

'The future of the industry is data-driven and therefore to make this future-proof, digitalisation needs to be implemented as soon as is possible'.

'If we stay the same, we will fall behind our competitors. We have no choice, adopt it or get left behind'.

Only two respondents touched on the third theme that Industry 4.0 can be used in a more positive sense as an enabler to grow the respondent's business. These two respondents suggested that

There are opportunities to improve manufacturing performance through application of Industry 4.0 technologies. This can give us an advantage when quoting for new business.

'We can grow as a business'.

Using Industry 4.0 to grow as a business will arguably provide a more proactive approach to business. Rather than keeping up with the competition, two potential innovators (Rogers, 1962) suggest that Industry 4.0 might instead be used as an enabler of growth. To recall, Industry 4.0 originally evolved as a competitive differentiator intended to allow the high wage economy of Germany to compete in a global marketplace (Kagermann et al., 2013, Alcácer & Cruz Machado, 2019).

What can hence be taken from this section on competition is the respondents' suggestion that Industry 4.0 remains highly significant to them because it is crucial for their organisations to stay competitive. A number of reasons were suggested for this, with one major factor being the fear of been left behind which is perhaps no surprise given the 'revolutionary rhetoric' used by the media and by technology and consultancy businesses. The use of business social media such as LinkedIn and online trade magazines may then be triggers causing a 'bandwagon' to form.

Given the revolutionary ideas first announced over a decade ago, it was surprising that so few within the sample were ready to adopt them. It might be said that a picture has emerged in this research that the fear in question is being used as a marketing tactic by some actors. It was revealed that two respondents see Industry 4.0 in a more proactive way and recognise its potential as a tool to assist in organisational growth.

5.4.6 Changes in Employment Levels

Authors such as Frey & Osborne (2013), Kusiak, (2018), Pereira & Romero, (2017) and Schröder (2016) suggest that the changes brought about by Industry 4.0 will indeed transform existing employment patterns within industry. This question is hence designed to establish within the sample questionnaire whether or not any changes in employment have occurred within their respective organisations. The question also sought to determine whether or not changes in employment have occurred because of technology implementation.

The findings then established that 19 of the respondents were unable to determine whether or not changes have occurred, while 10 of the respondent's suggested changes have occurred and 2 of them said that no changes had occurred. As has previously been highlighted, it is unsurprising then that 19 of the respondents were unable to determine whether or not employment levels have changed given that moves towards implementation have been slow, and microchip shortages have been caused in the automotive industry by the recent pandemic and issues around Brexit.

However, any impact on employment levels might be difficult to determine for many businesses at this moment in time. When the 10 respondents who suggested that changes have occurred were asked to explain, why this is the case two main themes were established: headcount fluctuation, and reskilling. Certainly, what the respondents suggested does correlate with the findings in the literature being that there is the belief that headcount will fluctuate or shift, although it was also suggested that workplace skills could be improved. Indeed, three of the respondents suggested the following possible outcomes: *‘Less people but more highly skilled’.*

‘There is still a need for human staff, but skill levels may have to increase’.

‘In some roles, however, it will open other doors to new roles’.

The first of these statements most likely suggests that the respondent has seen their organisation’s head count reduced as an effect of technology implementation. This idea about headcount reduction arguably indicates that productivity has been raised which many are suggesting is the overarching aim of Industry 4.0. This issue will be further covered below but in general, the three statements made by the respondents arguably convey a positive outlook as they all discuss new opportunities.

There is also the suggestion that evolving industrial technologies and processes naturally lead to changes in the labour pool for organisations. One example would be the wind power versus fossil fuels debate where there has not only been a shift in business practices but a disruptive shift in skill requirements. One could argue that as standards, reskilling and upskilling are both normal aspects of industrial evolution.

Regarding fluctuations in headcount, some of the respondents then suggested the following objectives should be taken into consideration:

‘Have to improve productivity eventually and ultimately reduce employment in a like-for-like basis.’

‘Head count reduction.’

‘Through implementation of COBOTS to determine whether headcount is reduced at a site level by reduced operators and increased support staff.’

Of the sample, several respondents suggest that the level of scepticism outlined within the findings is a natural human reaction. Technological advancements can scare people, with history showing that they fill them with anxiety and doubt while also affecting their everyday organisational life. Where some of the respondents discussed headcount reduction, others discuss redistribution. It might then be argued that this is a natural part of any programme for change as the skills required evolve as much as the technologies in order to support them. What might follow from the latter statement is the presence of a ‘skills shift’ where the focus moves away from routine work towards more advanced skills roles. As discussed above, this is arguably an accurate illustration of how skills evolve.

In summary, what the findings in this section revealed is that 19 respondents are unable to determine whether or not there have been any changes to employment levels since implementation of Industry 4.0. Again, this appears unsurprising given recent instability within the UK economy for the reasons outlined above. It was also revealed that the 10 respondents took headcount fluctuation as both positive and negative, and along with reskilling viewed these as the two major 'change’ themes. Where some have predicted a major decline in employment (Frey & Osborne, 2013; Kusiak, 2018), the evidence from the respondent sample does not support these claims. What might be concluded from the questionnaire survey then is that the consequence of major job losses which many have predicted has not yet occurred.

5.4.7 Learning and Development?

The aim of the final section of this impact section of this study is to determine whether or not the respondent’s organisations have been actively engaging with Industry 4.0 through a programme of learning and development. Here the concern is that if people don’t understand the technology, then how can they deploy it effectively? The existence of this issue may also suggest a level of recognition on the part of the site leadership team, being that learning and development may be a key enabler in successful implementation efforts. Nonetheless, business leaders might hold an alternative view insofar as deployment efforts are being driven by a small number of specialist people or external company support. The final part of this section hence examines the respondents’ thoughts on the skills requirements of the future.

According to the data given within the questionnaire, 9 of the respondents belong to organisations engaged in a programme of learning and development. This finding leaves 22 of the respondent organisations not having engaged in a programme of learning and development. Although the numbers speak from themselves, what is interesting is that the first section on knowledge revealed that 10 individuals had an advanced and extensive understanding of Industry 4.0. Overall then, 9 respondents stated that they have engaged on a programme of learning and development while 10 respondents suggested an advanced level of understanding. Although the number are remarkably similar, it cannot yet be that confirmed whether or not these findings are in direct correlation.

To add further interest, these numbers do appear to corroborate with the early adopters suggested by Rogers (1962). The adoption findings also confirmed that 8 respondents have engaged in organisational readiness which does corroborate with the previous finding on knowledge and impact. Perhaps what is beginning to emerge are the phenomena of 'adoption patterns' where successful early adoption seems to have a predetermined path which begins within knowledge acquisition. At the same time, although the evidence support the finding that the respondents view the implementation of Industry 4.0 as a critical part of competition, 22 of them were yet to engage on a programme of learning and development. Several different perspectives can be considered here but perhaps none of them can be validated without further research.

Do these findings then demonstrate that the respondents' organisations are aware of the technology implementation being performed by a third party, such as a consultancy? Or is it also demonstrable that many of today's business leaders fail to recognise that a programme of learning and development for staff is something which can be used effectively as an implementation enabler? Or as with the previous evidence from the literature review, perhaps people do not yet know where to begin with deployment efforts?

A final thought may be that Industry 4.0 is not yet fully 'on the agenda' for many organisations. This claim can again be supported by the empirical analysis and from the findings within the literature. Nonetheless, one positive to be taken from these findings is that 9 of the respondent's organisations are beginning to develop the internal capability of their teams which clearly suggests early adoption (Rogers, 1962).

When the respondents were then asked what they thought the skills requirements of the future would be, three main themes were established. The need to understand the basics of Industry 4.0 was the most popular response given, followed by improved maintenance skills and computer science. Beginning with the basics, the respondents suggested the following:

‘Understanding the benefits of i4.0 and how to physically apply it.’

‘Digitalisation, although we don’t know what that really means.’

‘Understanding of digital and how that can provide for an overlay to traditional manufacturing improvement techniques (lean 6Sigma, etc) to drive further incremental performance improvements.’

‘The digital basics.’

One conclusion to be drawn from these findings is that, within this sample, the respondents perhaps struggled to understand the basics behind Industry 4.0. This finding is a common thread running through these empirical findings, regarding which the third respondent statement here appears strongly in support insofar as it indicates that some of the respondents struggle to see the difference between traditional manufacturing and Industry 4.0. Perhaps what this finding demonstrates is the existence of a technology push as many respondents admitted to fundamentally struggling with the basics of Industry 4.0.

The second strongest theme to arise on the subject of the skill requirements of the future was the requirement for company personnel to possess more capacity for maintenance and technical skills. This finding may not come as a surprise given that Industry 4.0 is a technology-based improvement initiative. Specific skills within this area include AI, data analytics, modelling and programming, which can all be said to fit the skills requirements of the previous industrial revolution. The final sets of responses in the skills requirement section concerned ICT and computer-based skills which, again, come as little of a surprise given that Industry 4.0 is a technology-based solution.

One of the key skill requirements then missing from these findings is arguably the role of leadership, or more precisely, the role of leadership in the digital age. The reason why this is the case can be ascertained through the 17 years of training and consultancy experience amassed by the researcher. Notably, the researcher has learnt over these 17 years that one of the most critical factors which can either make or break deployment efforts is how leadership engages with a technology programme.

In summary, what has been discovered in this section is that despite such a large number of respondents suggesting that Industry 4.0 is essential to remain competitive, only 12% (n=76) have engaged on a programme of learning and development. It is evident that these early adopters are consistent throughout the previous finings. It may also be concluded that the existence of these adoption patterns may then provide a ‘map’ for use in charting the early engagement of Industry 4.0. The two other workforce skills requirements of the future then suggested by the respondents are maintenance and computer science skills. Overall, the respondents suggested that the skills requirements of the future will need to begin with the fundamentals behind Industry 4.0, which will mean getting back to basics with education and learning & development.

5.4.8 Impact Questionnaire - Summary

The picture beginning to emerge regarding impact is positive one, where 41% of the total sample (n=76) suggest that Industry 4.0 has impacted upon their business. Here there seems recognition that Industry 4.0 has a wider application than just manufacturing, while key performance indicators have been impacted the respondent’s businesses. Regarding the level of impact 22% (n=76) then suggested a positive and outstanding impact of Industry 4.0.

The reason for these findings is varied but one major theme is the advancements in data-driven real-time decision-making as an outcome which can definitely be associated with Industry 4.0. The general picture beginning to emerge then is that a small number of pioneers or early adopters are now beginning to see the impact of their efforts. It is arguable that this impact is only beginning to emerge, and that its full potential has yet to be observed.

The majority of the respondents then suggested that Industry 4.0 is an important factor in remaining competitive as a business. One major factor here is the fear of been left behind, which is arguably a natural human reaction. Arguably, this fear has been manifested in the ‘marketing hype’ used by provider marketeers. Interestingly, only 2 respondents here suggested that Industry 4.0 can be used in a more positive sense as an enabler to grow their business.

With regard to the questions about employment, it was then revealed that 19 of the respondents are unable to determine whether or not changes have occurred. This is no surprise given that the implementation efforts are slow and arguably only beginning to emerge, while the recent pandemic and Brexit situations have had an effect on employment levels in many businesses. From the 10 respondents who suggested that changes have occurred, they listed reskilling and headcount fluctuation as the two main reasons for changes in employment patterns. However, there have been no signs of major employment losses due to the implementation of Industry 4.0 despite what many have predicted and perhaps the reason why this is too early is the diffusion of Industry 4.0. Otherwise, there are some signs of reskilling from the respondents.

Moving over to the learning and development question, the conclusion to draw is that despite the majority seeing Industry 4.0 as an essential tool for remaining competitive, only 12% (n=76) have engaged with learning and development. Although this finding may seem small, it is arguably of significance that this small group of around 10 or so individuals have the most knowledge, have demonstrated organisational readiness as a prerequisite, and have engaged on a programme of learning and development. Perhaps what is beginning to emerge is ‘adoption patterns’ from within the sample. In a slightly more negative sense, 22 respondents have not yet engaged with Industry 4.0 learning and development despite its criticalness to competition which could be for several different reasons

The respondents also suggested that the skills requirements of the future will fall under three main themes: Industry 4.0 basics, maintenance, and computer science skills. One further skills group could be added to this number based upon his professional experience of the researcher. That is leadership skills or, more precisely, leadership in the context of digital.

However, there is still some conjecture with these findings, notably in the use of future tense words suggesting that the respondents were predicting what could happen rather than what has actually occurred. This has been a common theme throughout these findings. Despite observing some moves towards implementation within their organisation, some participants within the sample are yet to see any impact from Industry 4.0. Further investigation has identified a potential number of reasons which include organisations being too early to determine any definite impact, and the disruption to manufacturing UK manufacturing taking place over the last 12-14 months. Such findings come as no surprise considering the lack of Industry 4.0 knowledge identified, initially aligned to the fact that many respondents simply do not know where to start with acquiring this knowledge.

5.4.9 Impact Interviews - Introduction

Setting out to examine the empirical findings, this section on impact has been grouped into themes and initially begins with an exploration of the impact that Industry 4.0 has had on business. Within the context of this research, the term 'impact' indicates the tangible benefits to have come from adoption and implementation. Exploring the level of impact begins at its most basic level by discussing what impact has occurred within the interviewees' businesses since implementing what they believe to be Industry 4.0. The analysis following from this initial exploration will then seek to determine the main themes among those factors that have been inhibiting impact.

5.4.10 The Level of Impact

The first finding to be presented in this section is that level of impact within the sample has been somewhat positive although limited to very few of them. Only 2 respondents (KI:2 & RI:2) provided examples of companies they judge to have been impacted by Industry 4.0. As an industry consultant, respondent (KI:2) was able to provide examples of automated picking machines as well as driverless deliveries from third-party suppliers to a UK-based automotive OEM. The researcher can confirm that this example of driverless delivery is an actual project which has been underway for many years, although it is still in an experimental phase suggesting that a critical approach be taken to this test case.

Meanwhile, respondent (RI:2) suggested that there has been some improvement in data analytics while admitting that '*It's probably something which could have been done in excel rather than Power BI'.* In the grand scheme of Industry 4.0 to change one Microsoft software package to another does not arguably constitute a switch to Industry 4.0. For instance, the organisation to which respondent (RI:2) belongs has seen significant financial investment in implementing the Industry 4.0 agenda. What might then be taken from these findings is that a certain level of impact is reflected within a small section of the sample of the interviewees.

However, it is debatable whether these two examples really constitute Industry 4.0 technologies or whether what is being demonstrated merely involves evolving technologies. As stated in the literature review, automatic guidance vehicles are nothing new, although within the context of delivering from a third-party supplier to site they are arguably an innovation. The second example regarding the evolution of data analytics software might be thought of as similar. It might then be said that the evolution of technology here supports the conclusions that what is being demonstrated at the present time is evolution and not revolution.

From a slightly more negative perspective, one of the main themes to have come from the interview research is that in certain cases it appears too early to quantify the impact of Industry 4.0. Some participant suggested that in terms of impact, it is *'still too early to tell in this company as were only scratching the surface with it'* (RI:8) or there has been *'minimal impact'* (RI:4). Given the previous empirical research, these findings are perhaps unsurprising as the level of knowledge here is basic to limited, alongside the fragmented level of adoption. Moreover, these ideas around limited impact align with the findings drawn from the questionnaire research section. It may be argued that despite being ten years in the making, the rate of diffusion of Industry 4.0 given by this sample is perhaps within Rogers (1962) categorisation of early adopters. Such claims were supported by one interviewee (RI:2) whose organisation has seen significant investment in Industry 4.0 and who suggested that *'at the moment, I wouldn't say anyone is truly seeing the change.'*

In addition, (RI:2) admitted that

'I would imagine that the impact would be big if the technologies are use right and focus on our KPI's but as I say, there is nothing really happening here despite what is being fed to senior leadership'.

The conclusion to be drawn from the above evidence is that the some of the organisations in question want to be seen to be doing something which might be described as the adoption of Industry 4.0. However, the reality is very different and in alignment with the findings of the previous section on adoption. One interviewee (KI:3) also commented on this hypothesis of fake implementation by reporting that

'We make an announcement to the FT that we are going to do Industry 4.0, guess what? Our share price goes up exactly like Motorola and six sigma'.

Such evidence is again in alignment with the previous empirical findings that some companies would prefer to be seen as implementing Industry 4.0. While this statement cannot be confirmed or refuted, this is arguably a key factor to consider in understanding why impact of Industry 4.0 has been minimal.

In summary, when evaluating the data from both the questionnaire and the interviews it might be suggested that the findings do corroborate. The idea that Industry 4.0 is in its initial stages of diffusion within the UK automotive and manufacturing sectors is evident throughout. Moreover, there seems to be a misunderstanding of what the actual impact of Industry 4.0 looks like as some have suggested that it merely constitutes software packages and automatic guidance vehicles. It might also be confirmed that organisations have seen significant investment with little or no real change. This finding does support the previous conclusions that some interviewees still do not have knowledge of where to start adopting and implementing Industry 4.0.

From a more positive point of view, another common theme confirms that the interviewees have been engaging with what they generally believe to be Industry 4.0. Here at least three interviewees claimed that they were doing more than the others in terms of engagement and implementation which, as a finding, does corroborate with the ideas previous discussed with regard to early adopters.

5.4.11 Factors Affecting Industry 4.0 Implementation

It may be claimed that although the level of impact identified in both the questionnaires and interviews is positive, the real impact of Industry 4.0 is limited to these pioneers who are taking its implementation seriously and are leading the way within the industry. Logically then, the rest of this section on impact will focus upon the elements which have perhaps hindered efforts to implement Industry 4.0 within the sample.

Much as previous research had revealed that some people have a natural resistance to change, one of the more experienced OEM managers (RI:1) developed these ideas further within this section on impact by mentioning the writings of George Orwell (1903-1950), particularly the famous novel *1984,* published in 1949. This interviewee suggested that the impact of Industry 4.0 may be so profound that both society and business would feel the impact. Upon reviewing the transcript, it was not clear what the individual meant entailing that an email was sent to the interviewee asking for further clarification. The interviewee replied suggesting that

'George Orwell is an interesting character. In both 1984 and Animal Farm, he dehumanised the world in a way that tries to make us think differently. Particularly in 1984, he talks about the minority deciding on how the world exists and its policies and decisions: who eats, who doesn't; the use of automatons and machines. Both of his classics talk about obedience and control but most importantly, the challenge is what was real and what can be real. Although we talk about the Industrial Revolution, we also need to ask ourselves what is the driver today? Orwell is seen as a novelist, but it is his imagination or what he dares to imagine which is the same force behind the technological advancements that we are talking about'.

Orwell's novel *1984* predicted a new technological age of totalitarian control mediated through a state of dictatorship (Orwell, 2021). What the interviewee (RI:1) is suggesting here is that technological advancements might lead to another shift to new forms of social control. However, such a viewpoint could just be said to build upon the characteristics of natural resistance demonstrated by many people in times of change, merely suggesting a basic level of fear and some mistrust of the system. It is more than possible that Orwell's (1903-1950) writings around technological developments and ideas around 'Big Brother' have come to the fore in some people's minds when discussing industrial revolutions. Indeed, the interviewee stated at the beginning of the exchange that *'the power of the revolutions I only limited by our own imagination'*, perhaps suggesting that it is the fear of the potential of Industry 4.0 which is causing this level of anxiety. While some research does exist (Ito et al., 2021) exploring the characteristics of resistance to the implementation of Industry 4.0, these ideas around fear introduce a different level of complexity. Indeed, the theme of fear does not exist in isolation, as one participant the engineering director (RI:2) suggested:

'I don't really want to get to a point where everything is also fluent where there's no human interaction whatsoever because that makes us all kind of redundant.' (RI:2)

What this research reveals is that one of the factors arguably contributing to why the impact of Industry 4.0 has been so limited is fear. However, there may be a number of reasons why these interviewees are so fearful of Industry 4.0. Is this a genuine fear of the unknown, or perhaps a lack of understanding, or is it that some see the potential and recognise that both business and social change might not be for the best? Whatever psychology underpins this fear, it could be a significant challenge to overcome.

Another area in which the impact of Industry 4.0 might be limited is the shift to alternative fuel technology. There is evidence that organisations from within the sample have shifted the focus to electric vehicle and battery manufacturing. One of the interviewees noted that the biggest impact witnessed with the network is the shift to alternative fuel technology, particularly around battery technology and the electric vehicle. Here, KI:3 referred to

'The disruption caused by the planet saying that they do not want to use petrol engines anymore drives the technology implementation in different ways.'

From the perspective of an Industry 4.0 'purist', it is arguable that these two phenomena around are not mutually exclusive from any measures of Industry 4.0 implementation. Perhaps the purist view would then be that one can be used as an enabler of the other. However, the more pragmatic view might then be that the implementation of both phenomena would be too risky, costly and perhaps too much to do at once.

Table 5.10: UK car registrations by fuel type

December

	2021	2020	% change	Mkt share -21	Mkt share -20
Diesel	5,201	15,813	-67.1%	4.8%	11.9%
MHEV diesel	3,901	5,754	-32.2%	3.6%	4.3%
Petrol	42,048	58,494	-28.1%	38.7%	44.1%
MHEV petrol	12,715	13,629	-6.7%	11.7%	10.3%
BEV	27,705	21,914	26.4%	25.5%	16.5%
PHEV	8,336	9,130	-8.7%	7.7%	6.9%
HEV	8,690	7,948	9.3%	8.0%	6.0%
TOTAL	108,596	132,682	-18.2%		

Year to date

	YTD 2021	YTD 2020	% change	Mkt share -21	Mkt share -20
Diesel	135,773	261,772	-48.1%	8.2%	16.0%
MHEV diesel	98,753	60,953	62.0%	6.0%	3.7%
Petrol	762,103	903,961	-15.7%	46.3%	55.4%
MHEV petrol	198,025	119,179	66.2%	12.0%	7.3%
BEV	190,727	108,205	76.3%	11.6%	6.6%
PHEV	114,554	67,134	70.6%	7.0%	4.1%
HEV	147,246	109,860	34.0%	8.9%	6.7%
TOTAL	1,647,181	1,631,064	1.0%		

BEV - Battery Electric Vehicle; **PHEV** - Plug-in Hybrid Electric Vehicle; **HEV** - Hybrid Electric Vehicle, **MHEV** - Mild Hybrid Electric Vehicle

UK vehicle registration data (Society of Motor Manufacturers and Traders, 2022)

To validate the increasing quantity of alternative fuel types being introduced into the UK automotive sector, table 8.1 firstly outlines the December 2021 change and the year-to-date change. By December 2021, diesel engine use had decreased by 67.1% from the same month in 2020. Petrol engines were down 28.1% and battery electric vehicles up by 27,705 units at 26.4%. The year-to-date figures put battery electric vehicle use up at 76.3%. Although is important not to be misled by this data, it should be noted that only a small percentage of these cars are manufactured in the UK, although some interviewees highlighted that the battery electric vehicle market is growing in the UK.

These findings arguably provide an additional reason why the impact of Industry 4.0 has been limited within the sample; namely, the operational stability and lean maturity of the host organisation. A number of the interviewees suggested that the implementation of Industry 4.0 will depend upon the stability of their current operations. Perhaps what the interviewees are suggesting here is that if their existing operations do not achieve the predetermined performance then diffusion could take longer. The statement made by KI:3 was that

'From a manufacturing perspective it all depends upon where they are on the productivity journey as you cannot throw technology at people who have not thought about their productivity.'

Taking consideration of the above, it may be argued that the journey to achieving Industry 4.0 impact may be much longer than first expected. Indeed, three interviewees (KI:3), (RI:4) and (RI:8) suggested that Lean maturity might well be a prerequisite for technology engagement with Industry 4.0. Within this context, Lean maturity could be understood in terms of an assessment of how mature the organisation is compared to a predetermined set of assessment criteria. These criteria can focus upon operational stability elements including the level of standardisation, the achievement of key performance indicators and the level of active leadership among many other elements.

When drawing upon the researcher's practical experience, what is suggested by (KI:3), (RI:4) and (RI:8) arguably makes sense. Without an organisation having a stable base to work from, introducing the advanced technologies of Industry 4.0 might not the right business decision. If, to take an example, the host business is currently unable to achieve a better level of customer quality, cost and delivery performance, then operational efforts would be better focused upon customer requirements. This shift in focus might then delay any efforts to implement Industry 4.0, with any financial investments being better directed towards solving more immediate, pressing problems.

Nonetheless, many other operational variables should be considered if the claim is to be confirmed or refuted that Industry 4.0 technologies can be used to solve organisational problems. This pragmatic view of solving problems with technology is one that is echoed by interviewee (KI:3) who suggested a less purist view of Industry 4.0 where new technology is used to solve today's problems. As highlighted within the general overview section, this view does present limitations because just solving problems does not move the business forward. It might even be said that solving problems only allows business leaders to return to standards within operations. Taking these view into consideration, if the latter statement is true then lean maturity should not be a factor that inhibits Industry 4.0 deployment.

One other factor which can be taken from the research into why the impact of Industry 4.0 has been so limited is this notion of procrastination and global bureaucracy. Interviewee (RI:2) suggested that one of the challenges he faces is the necessity to pass through a global bureaucracy to get new initiatives confirmed. For larger companies, passing through a global hierarchy can be somewhat of a challenge and Industry 4.0 could potentially add more 'red tape' to the implementation efforts. The confirmation of capex allocation is perhaps one notable challenge, but other concerns such as local infrastructure, site leadership and culture, and all the bureaucracy which comes with working for global companies, may also slow down implementation efforts. Interestingly the interviewee did offer a solution for overcoming this level of procrastination in terms of breaking company activities down into manageable subsections and just getting on with the work. Other ideas around corporate politics and procrastination are evident in the adoption section of this thesis.

In the latter stages of the impact section, the interviewees were then asked about negatives with the implementation process. Most of what was highlighted has already been discussed such as corporate bureaucracy, fear and the lack of people engagement. However, two additional factors were highlighted during the interviews, which were the main themes of organisations not getting it right at the beginning, and companies experiencing disruption. Here, one of the interviewees (RI:5) suggested that their organisation will not invest enough time into understanding the systems, processes and people. The knock-on effect has resembled what they witnessed in their Lean journey insofar as *'our attempts to deploy will be fraught with problems and at a point it will create a white elephant'.*

Arguably what the interviewee is suggesting is the recognition that some organisations want to be seen to be engaging with Industry 4.0 even if the reality is much different. As discussed throughout the research, there might be several reasons for these perceptions. What was revealed early within the empirical investigation is the lack of planning, financial investment, organisational readiness and the lack of general understanding of Industry 4.0. What has then been discussed by the interviewees is subsequently in direct correlation to what has been found within the wider research. Indeed, it would appear that many companies are not starting their digital journey in the correct way as many of the prerequisites are missing. Here (KI:1) provided a very interesting point of discussion regarding the negative aspects of the attempts at technology implementation.

‘Yeah, there are always some negatives, and those negatives are about. For example, sustainable energy sources will put some of their previous energy suppliers out of business and that shift therefore has some pain.’

At this point, KI:1 suggested that the introduction of Industry 4.0 had the possibility to create a significant level of destruction (Joseph Schumpeter, 1883-1950) within industry. The knock-on effect would be the demise of one business and the rise of another. As highlighted elsewhere in the research, creative destruction (Joseph Schumpeter 1883-1950) is a standard part of how industry evolves. Scattered throughout history are examples of new innovations causing the demise of business, with the entertainment industry being one recent example of this. Where there were traditional home movie rental businesses, online streaming is now the preferred viewing choice of many.

The potentially disruptive nature of Industry 4.0 at this point in its diffusion is difficult to predict. From the findings, it might be suggested that a skills shift could occur but what sectors will be disrupted is difficult to predict. There is a growing body of research looking at the disruptive elements of Industry 4.0 (Bongomin et al., 2020; Choi et al., 2021; De Propris & Bailey, 2020; Nakagawa et al., 2021). Perhaps what can then be taken from this short section discussing disruption is that the interviewees recognise that for industry to develop, it must evolve. If Industry 4.0 was a revolution, then elements of disruption within the sector would be expected. However, what can be taken from the research findings within this sample of UK manufacturing and automotive is the belief that Industry 4.0 is an evolving technology strategy. Early adopters do exist but what has been revealed here ae evolving technologies rather than the revolutionary ideas suggested by many.

Interestingly when questions were asked about the skills requirements for the future, two themes emerged from the findings focused on the classification of hard and soft skill requirements. Nine of the twelve interviewees suggested hard skills were more valid, which are traditionally technical skills including programming, computer science, control engineering, configuration engineering (Industry 4.0 architecture) and data analysis.

(RI:1), who is an experience OEM manager, then admitted that

'I think that there's two for me. One is as we as we said, we need the analysers, you know, the people who can manage data and analytics but, they need to be complemented by people who understand the mechanics, or you know, and I mean mechanics in its broadest sense, how it, how it works and why it works and why it should work in that way.'

Then (RI:2) gave a similar response emphasising that if technical skills are required, then individuals are also needed who understand how technological implementation fits into overall business needs. In the context of the research explored in earlier sections of this thesis, these individuals might be thought of as Industry 4.0 architects. The necessity of possessing a harder skillset is not surprising given the nature of Industry 4.0. However, what comes as a surprise is that only three of the interviewees discussed the softer or more behavioural elements for skills development. Indeed, (RI:5) stated that

'People will look at the hard elements I bet but what we need is the right leadership to take this forward'.

(KI:1) and (RI:9) also discussed *leadership behaviour and analytical skills* along with *attitude and capabilities.* These topics have certainly been discussed in detail earlier within the research. However, based upon experience of Lean implementation it is the view of the researcher that the significance of the people engagement element should not be underestimated with regard to Industry 4.0. Leadership capability and vision may be critical factors in achieving successful Industry 4.0 deployment. Without successful leadership and staff engagement, then efforts to deploy Industry 4.0 may be fraught with challenges.

In summary, it was recognised from within the interviewee sample there are some positive signs that Industry 4.0 is underway is whatever form. However, the observation of actual impact was limited to three of the 12 interviewees. It has been established within this section that there may be several reasons for this. Fear is a common factor in both the questionnaire and interview findings. For instance, the most experienced interviewee, who had over 40 years in manufacturing, was the participant discussed the George Orwell novel *1984* in the context of technological advancement leading to obedience and control. Orwell's book perhaps provides an unlikely scenario, but it resonated enough for the interviewee to bring it up.

Fear is also manifest in the potential of job losses which is another common theme within the research. Interestingly, interviewee KI:3 with his extensive automotive network suggested that the shift from combustion engines to electrification is another a factor explaining why so many within the network are only just starting on the Industry 4.0 journey. Here, supporting evidence has then identified validating the claims of the KI:3, while it was also revealed that some of the interviewees suggest manufacturing stability to be a prerequisite for Industry 4.0 implementation. Although the logic behind this claim makes sense, in reality this may not be the case.

Finally, procrastination and bureaucracy were named as other factors which might inhibit implementation efforts especially for the more international businesses. When discussing with the interviewees these negatives in the deployment of Industry 4.0 a number of factors have arisen: corporate bureaucracy; fear; lack of people engagement; not getting it right at the beginning; and the potential for disruption. Finally, when the respondents were asked about the skill requirements of the future, two main classifications come through. The hard skills cited relate to the more technical skills while the soft elements relate more to requirements for leadership skills.

5.4.12 Impact Interviews - Summary

What can be drawn from this section on impact interviews is firstly that the general outlook for Industry 4.0 is positive, and secondly that all the interviewees are engaged with efforts towards the introduction of Industry 4.0. However, the actual impact discussed here only covers the early stages of its diffusion within the UK automotive and manufacturing sectors. There was evidence throughout the interviews that only a small number of early adopters who are leading the way with implementation efforts. This finding is common throughout both impact sections so the findings here are arguably what was to be expected given the rate of diffusion.

The upshot is that Industry 4.0 is now on a diffusion journey but only a small number of pioneers are leading the way and the majority are playing catch up. The respondents also identified a number of factors which would be impeding the implementation efforts. These include fear of change manifested in various forms, electrification within the automotive sector, operational stability, procrastination and bureaucracy. The negatives of implementation include lack of people engagement, not getting it right from the beginning and the potential of disruption. Alternatively, the factor listed as ‘not getting it right from the beginning’ can be thought of a lack of planning and setting clear expectations.

The adoption findings had established that only 18% (n=76) of respondents confirmed a strategic plan to implement Industry 4.0 within their respective businesses. What is revealed in the interviews does then corroborate with previous findings, suggesting that the factors which should be most considered as Industry 4.0 are diffused within the manufacturing and automotive sectors.

5.4.13 Impact Summary

By bringing both the questionnaires and interviews together it is possible to draw similarities between their findings. The picture beginning to emerge is of some positive signs of the impact of Industry 4.0 within the sample. Clearly, a small number of early adopters are doing more than most with Industry 4.0 where a pattern in adoption has been uncovered in which the pioneers have better knowledge than most, meaning that they have engaged in a programme of learning and development and engaged in organisational readiness. These findings do align with the interviewees insofar as around three of the 12 interviewees seem to be further into the diffusion than most.

It may thus be concluded from the sample that there are indeed companies who are engaging with Industry 4.0 and are now witnessing some impact. However, this engagement is only beginning to emerge with implementation efforts only starting to materialise for a small but distinct group of individuals. The impact witnessed so far is more in line with evolution and development, supporting the idea that Industry 4.0 is not for the moment a revolution, but an evolution for UK industry. Clearly something new is evolving, as borne out from within the sample, and there are signs that a high technology strategy is starting to be put in place, but the emphasis remains on emerging trends.

Nonetheless, the questionnaire results suggested that the impact of Industry 4.0 has been more widespread than the interview findings. At the same time, there may be a number of reasons for this greater impression of impact, beginning with the conjecture identified during the questionaries. Arguably, many of the terms used during the questionnaire use future tense words to suggest the potential of Industry 4.0. In this sense, the questionnaire gives an inflated impact figure of 41% suggesting that Industry 4.0 has impacted upon their businesses. The interviews then bring a more grounded finding insofar as 3 of the 12 (25%) interviewees suggested that Industry 4.0 has impacted their business.

Although there is some debate over the numbers here, the overall picture is still positive being that there is evidence for a small number of individuals seeing the impact of what they believe to be Industry 4.0. Contrary to what many have suggested, there is no supporting evidence to confirm that major job losses are to be expected through the deployment of Industry 4.0. Granted there has been some fluctuation and shift, but this evidence does not support major job losses.

Conversely, contrary to the positive steps outlined above, some of the respondents and interviewees have yet to witness any impact of Industry 4.0. Others have suggested that it is too early to determine any impact, which is again a common theme within the research and supports the ideas relating to the rate of diffusion. Perhaps what has been demonstrated from within the sample is the classic diffusion of innovation (Rogers, 1962) insofar as Industry 4.0 is slowly being diffused and what is currently being witnessed is the exception rather than the rule.

The respondents and the interviewees also suggested a number of reasons for the slowness of diffusion. These included disruption to the manufacturing and automotive markets cause by Brexit; the pandemic and ongoing microchip concerns; fear of change manifested in various forms; electrification within the automotive sector; operational stability; procrastination; and bureaucracy. What might also added to this list is the lack of people engagement from the beginning, which again suggests the lack of a clear plan and has been a common finding throughout.

Reference in the research to the skills requirements of the future have yielded similar results, especially with regard to the harder skill-sets. Both interviewees and respondents suggested that technical skills will be a major requirement in the future built on a foundation of back-to-basics in understanding Industry 4.0. At the same time, the interviewees suggested that leadership or a softer skill-set will also be needed to underpin the change needed to implement Industry 4.0 effectively.

Chapter 6 - Conclusion

6.1 Introduction and Research Overview

As a concept, Industry 4.0 can be understood as an emerging technological movement with its foundations in the 2011 high-technology manufacturing strategy first put in place by Germany's government. This thesis has thus set out to explore how UK automotive manufacturing businesses are adopting the principles and technologies of Industry 4.0.

This final section of the thesis will hence draw together the main conclusions established from within the research. The organisation of the conclusion is around three section questions intended to present in detail what the UK automotive manufacturing industry has found about the level of awareness of Industry 4.0, the level of adoption, and the overall impact of Industry 4.0. Nonetheless, the following conclusions are not generalisable to the whole of the UK automotive manufacturing industry.

This chapter initially provides a rationale for the project, outlining why the topic selected has been a valuable one to study. The section following provides a brief overview of discussion of the research method selected as most suitable for fulfilling the project's aims. Having been taken from the initial interview research, the study's main themes are then outlined while both the questionnaire and interview findings are presented for a final time in relation to the structure of the research, so providing the conclusions of the main research findings.

The final section provides a discussion of the contributions of the study to the existing body of research knowledge. It also outlines the practical aims and strategy of UK industry today and in the future.

6.1.1 Research Rationale

In trying not to be caught up with this 'band-wagon' of hype, it has proven difficult for initial research to establish whether or not Industry 4.0 or the Fourth Industrial

Revolution is just another movement which has transitioned in and out of industrial ‘fashion’. The prediction of many was that this ‘Fourth Industrial Revolution’ would transform industry and produce a dramatic impact on operational performance as well as cause a significant declining blue-collar employment. The issue has received a great deal of interest and attention from colleagues both within the consultancy fraternity and from within academic circles. Although the preliminary literature research found lots of consultancy research and a growing body of academic literature, it proved difficult at the proposal stage to establish an agreed definition of Industry 4.0.

The idea of Industry 4.0 may have first been developed by the German government, but it then elicited more interest from industry and research institutes. This interest on the part of German research institutes could arguably be explained by the dominance of Germany’s engineering and automotive manufacturing industry. Nonetheless, similar initiatives were also launched by governments around the world, including the UK, which added further interest to the task of establishing what this industrial movement is about. The evidence of the initial research was that the phenomenon of Industry 4.0 was not clearly understand, yet all over the world governments have been starting to rethink industrial strategy and make significant efforts to work towards a digital future.

Having worked within the automotive manufacturing sector since 1996, Industry 4.0 was of personal interest to the researcher. The companies with whom the researcher has worked were also likely to be the ones due to be impacted significantly by this industrial phenomenon. The other main motivation behind undertaking this academic study was to use the DBA research process to make sense of this complex movement in a logical and unbiased way.

6.1.2 Research Methodology

The level of understanding around Industry 4.0 has developed over time and in the realisation that this is a new phenomenon, the research philosophy selected to yield the best overall results overall was pragmatism. The advantages of the pragmatist approach is its flexibility and its unbiased perception that Industry 4.0

is an emerging phenomenon and so understanding people's level of awareness, adoption levels and overall impact are significant unknowns. Pragmatism hence ensures that there are no preconceived ideas or philosophical assumptions made prior to the beginning of the study and that the research questions themselves will form the main part of the project.

6.1.3 Research Strategy: Questionnaire Survey and Interviews

A two-stage sequential research strategy was employed to achieve the research results. The questionnaire survey yielded a 38% response rate made up of the researcher's network. Subsequently, 12 interviews were performed with various people from within industry, academia and the consultancy sector, although all the interviewees could be said to hold senior positions within industry.

However, initial engagement with the various manufacturing, government and automotive bodies of the UK was almost non-existent, as people did not seem to want to talk about Industry 4.0. In fact, one research institute did engage but through the discussions they admitted that Industry 4.0 was not something on their research agenda. This led to the researcher using his own network.

6.2 Conclusions

6.2.1 General Thoughts

As highlighted in the previous section, the rationale for asking open questions to gauge people's general thoughts about Industry 4.0 was to gain some general sense of the views, perspectives and opinions of the interviewees. In allowing the research participants to answer questions free of guidance or prompts, the interviewees were given free rein to express their thoughts. Moreover, the design of the question allowed the interviewees to provide free-flowing answers when exploring the concept of Industry 4.0.

6.2.2 General Reflections

Several broad themes emerged during the initial discussions with the interviewees. Although four separate themes were identifiable, all of them were arguably related. One of the first themes to emerge was the use of jargon and buzzwords familiar to many as marketing tactics. Consideration of their use here resulted in the admission by the interviewees of general confusion and lack of clarity regarding the concept of Industry 4.0.

The second theme to emerge from this initial section was the idea that what has been sold in the name of Industry 4.0 has been repackaged technologies, or 'old wine in new bottles'. When the consultants and technology providers gave evidence that old technologies had been repackaged as 'Industry 4.0 ready', the impact on the interviewees was again a feeling of confusion and lack of clarity in their organisations.

The third theme then to emerge is the admission that a significant push towards Industry 4.0 has come from the consultancy fraternity. Many of the interviewees have been inundated with requests for meetings and contact with marketing campaigns, many of which have been selling what were supposed to be the revolutionary ideas of Industry 4.0. The interviewees also provided evidence to suggest that these moves are coming not just from consultants, but from technology providers and manufacturers.

6.2.3 Comments on the General Reflections

The consultants and technology providers appeared to be using buzzwords, jargon and other so-called revolutionary rhetoric as marketing tactics to engage with the interviewees on their journey to Industry 4.0, all of which is outlined within the literature (Buer et al., 2018, p. 3). This marketing hype had caused confusion amongst the interview sample leading to their conclusion that the concept was simply 'old wine in new bottles' (Kolberg & Zühlke, 2015; Drath & Horch, 2014) The interviewees suggested that what is being sold is repackaged technology which does not lead the researcher to conclude that Industry 4.0 is in any way revolutionary. The conclusion to be drawn here is that some providers are using supposed revolutionary ideas as marketing tactics.

6.3 Research Question 1: What is understood by the term 'Industry 4.0' within the Automotive Manufacturing Industry

The aim of the first question was to explore the general level of awareness of Industry 4.0, determining whether or not the respondents were aware of Industry 4.0 at all, and then exploring how detailed their awareness was given its relevance to the automotive manufacturing sample. Existing knowledge of Industry 4.0 was explored on several levels, first by asking the respondents to describe Industry 4.0 and subsequently by asking the interviewees to describe their level of understanding. Further validation of knowledge was then made by asking the respondents to indicate their level of understanding of the technologies associated with Industry 4.0. The overall findings for RQ1 have then been summarised in 3 key points.

6.3.1 Level of Awareness

Here general awareness was low as 30% (n=76) in terms of the number within the research sample who never heard of Industry 4.0. If anything, the overall lack of awareness may have been underestimated as a further 8 colleagues had refused to complete the questionnaire, admitting that they had never heard of Industry 4.0 before. The general finding here was that the level of awareness from within the sample was low overall.

When mining for understanding by asking the respondents/interviewees to describe Industry 4.0, the level of understanding was also found to be low. What the respondents failed to describe was the difference between today's technologies and those of Industry 4.0, with many simply describing today's evolving technologies. Consequently, it was concluded that the term 'Industry 4.0' meant different things to different people.

Many of the interviewees used words such as 'amateur', 'very limited' and 'novice' to describe their level of understanding. This low level of knowledge was confirmed by the respondents within the technology groupings section who described their knowledge as being basic to limited. One interviewee confirmed that there was a similar situation within his network, suggesting that their level of understanding is on a level of 3-10. This finding corroborates with the other conclusions outlined above, suggesting that despite the efforts of many the overall level of understanding is low. Overall, it is clear from the evidence given within the survey that what most interviewees were suggesting in their responses were the possibilities of Industry 4.0 rather than the actual realities of the technologies as they exist today.

6.3.2 Comments on the Level of Knowledge

Initially this low level of knowledge was a significant finding given that Industry 4.0 has been 10 years in the making, via media hype and the push coming from technology providers. Moreover, this finding is not to overlook that similar initiatives have been developed around the world and the fact that the UK government launched its own future of manufacturing initiative in 2013.

Moreover, the individuals targeted by the questionnaires and interviews were those who are likely to be involved with the push to Industry 4.0. In general, the automotive industry may lead the way in innovative solutions, but overall the level of knowledge from within this sample is limited. This is something which is aligned within the literature as there is still much debate surrounding a clear definition of Industry 4.0 (Alcácer & Cruz-Machado, 2019; Culot, Nassimbeni, Orzes, & Sartor, 2020; Ghobakhloo, 2018; Glas & Kleemann, 2016; Mrugalska & Wyrwicka, 2017). It may be concluded then that the term ‘industrial revolution’ is too strong at this moment to describe Industry 4.0 from within this sample of UK automotive manufacturing.

6.3.3 Drivers of Industry 4.0

Nonetheless, the picture is not entirely negative as a small group of pioneers clearly demonstrated a more sophisticated understanding of Industry 4.0. This finding is also confirmed within the multi-level analysis, with a group of around 13% (n=76) of the respondents providing a richer description of Industry 4.0.

These findings corroborate what has been found within the interviews insofar as a small number of individuals seem to have a more sophisticated understanding of Industry 4.0. This small number of pioneers was again confirmed in the questionnaire section on technology, therein constituting a small number of people with a greater understanding than the majority.

6.3.4 Comments on Drivers of Industry 4.0

That there is a small but distinct number of individuals who do have a more sophisticated level of understanding of Industry 4.0 and its associated technologies is evident from both research instruments - the questionnaire and interviews. Again, the fact this figure is around 13% in both cases does suggest that some positive steps have already been taken towards understanding Industry 4.0.

6.3.5 The Push for Industry 4.0

There is clear evidence to suggest that a significant push towards Industry 4.0 has come from the technology providers and consultants. These individuals have been talking up Industry 4.0 and, in some cases, the marketing drive has been so extreme that a small number of individuals have switched off to the idea of Industry 4.0 completely. In some cases, what has been sold is old technology repackaged as Industry 4.0 ready or compliant which, as a finding, corroborates with the idea that Industry 4.0 is about technology *evolution* rather than industrial revolution. The use of buzzwords and high-technology phrases by the technology providers and technology companies were found to have different meaning to different people which all adds to the level of confusion surrounding this phenomenon.

6.3.6 Comments on the Push for Industry 4.0

The technology providers and consultancy companies in the automotive manufacturing sector seem themselves to have been adding to the level of confusion by using buzzwords and jargon to support the marketing campaigns. The examples where technology providers are repackaging old technology as Industry 4.0 ready added once again to the level of confusion from within the research sample.

In a small number of extreme cases, people have been switching off to the ideas around Industry 4.0 due to the misguided efforts to promote the phenomenon on the part of some consultants and technology providers. These findings certainly corroborate with some of the themes emerging from the previous sections.

In summary, an interesting picture was beginning to emerge insofar as around a third of the questionnaire survey respondents were unaware of Industry 4.0. Given the focus of the research was targeted at the sectors and people within the sample who are likely to be involved with Industry 4.0, this is a significant finding. In contradiction to this there are an emerging group of around 13% which clearly know more than most. It may also be concluded that the level of understanding of the technologies are limited, and that there is a significant push coming from the technology providers and consultancy fraternity.

6.4. Research Question 2: To What Extent are UK Automotive Manufacturing firms Adopting Industry 4.0?

The research question considered in this section seeks to understand the level of Industry 4.0 adoption within the sample. Here the term ‘adoption’ indicates that organisations are using Industry 4.0, be that in terms of technologies commissioned, installed or starting to be used.

The idea behind this section was to go beyond what people ‘know’ and explore what people are doing regarding the adoption of Industry 4.0. This was first achieved by asking the respondents and interviewees if they have adopted Industry 4.0 in some way.

The next stage of the research question was to understand which technologies have been adopted and gauge the reaction of the interviewees and respondents. The final stage was to understand some of the challenges faced throughout the adoption process.

6.4.1 Level of Adoption

Here, what was confirmed from within the research questionnaire survey is that just shy of half (n=76) of the respondents suggested that their organisations have adopted Industry 4.0 in some way, mainly within production-related areas. While this finding is arguably a positive sign of adoption, it might also suggest a level of conjecture throughout the findings, as most of the respondents failed to distinguish between today's technologies and that of Industry 4.0. To take an example, only one individual from the sample reported that cyber physical systems are currently in place within their organisation; a significant finding as Kagermann et al., (2013) suggest that this technology underpins Industry 4.0. In addition to the above finding, it should be recognised that a low number of respondents suggested that cyber physical systems will be implemented over Years 2 and 3.

These findings are supported by the evidence of the interviews where two interviewees confirmed that significant investment has been made to their organisation, but most of the staff still do not understand Industry 4.0 including the interviewees. Nonetheless, when the respondents and interviewees were asked which technologies are currently in place, it was found that the top five are cloud computing, smart manufacturing technologies, smart working, smart products and analytics.

6.4.2 Comment on the Level of Adoption

The picture does seem positive as around 50% of suggest that their organisations are adopting Industry 4.0 in some way. However, due to the lack of knowledge and the confusion between today's technologies and that of Industry 4.0, what is arguably being implemented is what people believe to be Industry 4.0.

Some supporting evidence here comes from the fact that cyber physical systems are still not on the agenda of many organisations and appear not to be for the coming two years. This suggests that many industry stakeholders still do not understand Industry 4.0 and are naming any technology adoption ‘Industry 4.0’.

6.4.3 Plans and Budgets

Considering that around half of the respondents outlined above suggested that adoption has taken place, the evidence is that a small number of respondents and interviewees have plans in place and budgets allocated while some have even done a readiness assessment. However, a more realistic figure of people who have adopted the new technologies is around 13%, so constituting what Rogers (1962) calls the ‘early adopters’ who are arguably the pioneers of Industry 4.0. From these findings, it may be concluded that around 13% of the research sample have committed plans and budgets, which is clear evidence of Industry 4.0 adoption. Here, the findings do corroborate with those of the knowledge section.

However, despite being ten years in the making with all the media hype in attendance, according to the research sample Industry 4.0 is still very much in its early stages of adoption. The ideas around the Fourth Industrial Revolution are perhaps somewhat unrealistic at present, entailing that evolution rather than revolution may be a more appropriate term to describe the emergence of Industry 4.0.

Perhaps what the findings actually represent are the respondents’ individual journeys upon the path of diffusion, where diffusion has just started for the majority and where only a small number of early adopters have progressed further than most. Arguably what has been revealed here is just a natural part of the rate of diffusion, which means only that general progress is being made towards Industry 4.0

6.4.4 Comment on Plans and Budgets

It is clear that around 13% of the total sample (n=76) are ‘early adopters’ which is a finding of some significance within the research. With plans in place and budgets allocated, this 13% of respondents were making serious steps towards the adoption of Industry 4.0, which contrasts with the earlier findings on initial awareness of Industry 4.0. Early adopter is a term used by Rogers (1962) to define a stage of innovation diffusion which outlines the life cycle of a product adoption.

However, the rate of diffusion is slower than many perhaps hoped. For most industrial stakeholders, diffusion is only beginning although there are signs that progress is being made. However, what was generally observed within the research sample of UK automotive and manufacturing firms is more associated with evolutionary rather than revolutionary developments.

6.4.5 Inhibitors in Adopting Industry 4.0

As identified by the interviewees and respondents, several inhibitors or barriers to the adoption process have become apparent. The research has revealed that some of the respondents and interviewees do not know where to start within Industry 4.0 as it is a complex phenomenon. It may be concluded that some organisations are not even ready for early adoption due to procrastination, corporate bureaucracy, poor leadership, low levels of knowledge and the perception that Industry 4.0 is a high-cost strategy.

The above issues are additional challenges faced by industry where, as previously revealed, the evidence accumulated in both research instruments demonstrates a general lack of knowledge of Industry 4.0 and its associated technologies as a key factor underpinning these barriers to adoption. Although the evidence suggests that plans are in place for Industry 4.0 adoption, about 87% of respondents and interviewees suggest that they are not. As discussed, without clear direction, readiness and prepared budgets then efforts for adoption are likely to be inhibited.

6.4.6 Comments on Inhibitors in Adopting Industry 4.0

Clearly there will be challenges for many when deploying Industry 4.0 within the British business sector, although rather than being inhibitors to implementation efforts it is more a question of challenges which some have faced. The findings also suggest that adoption is complex which might also be putting people off from adoption. Moving forward, these challenges may be considered as factors in stimulating those efforts to increase adoption by learning from the challenges faced by others.

In conclusion, the picture emerging is that there are indeed signs of early adoption of Industry 4.0. This evidence has been confirmed from within both the questionnaires and interviews. There is evidence that a small number of early adopters are engaging with Industry 4.0 both strategically and financially, which suggests some are taking adoption efforts seriously. There is also evidence to suggest that there are a smaller number of innovators who are taking this one step further and performing a form of organisational readiness which arguably focuses the organisation on where to deploy. However, Industry 4.0 adoption is slow, and the majority of interviewees and respondents are just beginning their journey. Despite 10 years in the making and many (Kagermann et al., 2013; Lichtblau, 2015; Schwab, 2016) calling it the 4th industrial revolution, Industry 4.0 is just beginning to emerge within UK automotive manufacturing.

6.5 Research Question 3: What is the Impact of these Technologies on Business and Workers?

This section presents the third stage of the overall research. Initially, the research set out to understand the level of awareness and knowledge of Industry 4.0 and its associated technologies. This stage was followed by the pursuit of an understanding of how many in the sample are adopting Industry 4.0, and whether or not the respondents and interviewees are doing anything about it.

The final section set out to understand whether or not Industry 4.0 has been significantly diffused in terms of the ability of the questionnaire respondents and interviewees to confirm that some impact has been achieved. The aim of the final question was thus to uncover the level of impact that Industry 4.0 has had.

This section seeks to uncover whether or not some of the trends suggested by many within the literature have actually occurred, such as mass jobs losses.

6.5.1 Impact of Industry 4.0

As discussed previously, what was revealed in the overall questionnaire is that of the 76 respondents, 35 suggested that they are adopting Industry 4.0, while 31 respondents have been seeing some form of impact. These findings do appear to indicate that substantial progress has been made towards Industry 4.0.

A multi-level analysis was then performed to confirm the impact in more detail, by asking the respondents which key performance indicator has been impacted the most. The key performance indicator for productivity emerged as the most impacted measure. A similar method was used to ask the respondents which area of their business was impacted most. Again, the working environment was reported to be the highest impacted area within their organisational and business context.

Arguably, these findings are what one would expect given the general role of respondents within operations. Further analysis then confirmed that 22% of the total respondents (n=76) suggest that the overall impact of Industry 4.0 upon their business has been positive and pronounced. However, although the picture above does indicate progress towards Industry 4.0 there is a degree of conjecture present throughout the findings. What most of the interviewees actually suggested are the potential implications of Industry 4.0 having an impact upon their host organisations, which can be justified through the respondents' use of the future tense. The respondents tended to suggest what the impact of Industry 4.0 might be in the future rather than what is occurring at present.

The above findings are hence aligned with what was uncovered from within the interviews, where only a small number of people have seen a significant level of impact. It may be said then that a realistic picture remaining consistent throughout the research lies with the fact that 13% of the respondents appeared to be an early responder group, which is evident throughout all the sections of this thesis.

6.5.2 Comment on the Impact of Industry 4.0

Although there are some clear, positive signs of the positive impact of Industry 4.0, the reality is that diffusion is still very much in its early stages. Hence, the more realistic figure of actual impact based upon what emerged from the interviews and questionnaires remains at around 13%. From an output perspective (Slack et al., 2019), productivity as the key performance indicator is where most impact has been confirmed. The reason why this level of conjecture exists is down to the inability of some to distinguish between what are today's evolving technologies and those of Industry 4.0.

6.5.3 Emerging Industry 4.0

Evidence from within the findings suggests that the interviewees have provided a more pragmatic view of the impact of Industry 4.0. Around 5 of the 12 interviewees confirmed that despite implementation occurring, they have yet to see any impact of the new technologies. What can be concluded is that although implementation has occurred it is still too early to determine any impact of Industry 4.0 within the interviewees organisations. It has also been revealed that Industry 4.0 is diffusing at a slow rate within the UK automotive manufacturing and in many cases just beginning to emerge. It can hence be concluded that within UK automotive manufacturing the slowness in diffusion and for those who have engaged its it still too early to establish any impact.

6.5.4 Comment on Emerging Industry 4.0.

It may now be confirmed that despite ten years in the making, the evidence from within this sample of UK automotive and manufacturing companies is that the general level of diffusion of Industry 4.0 is slow. What can thus be drawn from this finding is that Industry 4.0 is just beginning to emerge from within the sample. Despite the efforts of some to implement Industry 4.0, it is still too early to confirm widespread impact from within the research.

6.5.5 Employment

Only a small number of respondents suggested that they have seen changes to employment levels due to Industry 4.0, the reasons for which being headcount fluctuation and reskilling. However, there is no evidence to suggest that mass jobs losses are evident within the sample despite what many are predicting (Frey and Osborne, 2013; Kusiak 2016). Although people have both witnessed and predicted a shift in skills (Pereira and Romero, 2017; Bonekamp and Sure, 2015) mass job losses have not been evident. The respondents do suggest there will be changes to employment, but this might be due to a fear of the unknown which is causing this level of anxiety.

The research instead revealed that the various fluctuations within the economy over the past number of years due to Brexit, Covid-19 and parts shortages have made any real impact on employment difficult to understand within the context of Industry 4.0. However, the evidence does not support what many have suggested that the implementation of Industry 4.0 will lead to significant job losses.

6.5.6 Comment on Employment

Despite what various authors have suggested regarding the unemployment caused by the technological change presented by Industry 4.0, the evidence does not support these claims of significant disruption to employment. Although people have suggested some changes, the job losses predicted have not been confirmed within this research.

A 2013 industry-related publication by Frey and Osborne (2013) predicted that within the next two decades the potential implications of AI and automation will put 47% of American jobs at high risk. Even nine years later, similarities cannot be drawn on such a claim within the UK automotive manufacturing sector, where predictions of industrial revolution leading to a dramatic fall in unemployment have not been substantiated by this research.

It should hence be concluded from the findings that what is presented from the interview sample does not look like a revolution from one of the sectors where Industry 4.0 would arguably be most likely to be used. However, there are clear signs for progress or ‘early adoption’ and in impact has been suggested through the productivity key performance indicator. The research interviews revealed that even through implementation has occurred, it is too early to see much in the way of tangible benefits. Although the unlikely idea of mass job losses has not been configured within the findings, given the early stage of the rate of diffusion this was never likely to be the case.

6.6.0 Research Limitations

As always, research does present its own limitations. Although the survey questionnaire was issued throughout the network of the researcher, the sample could have been bigger which might then have created a larger response rate. One other weakness is arguably that the researcher used his own network, so opportunistic sampling tended to come into play as the research evolved. The researcher can definitely be said to be in a unique position given the size of the automotive manufacturing network which has grown over the 20 or so years within the industry.

Another weaknesses may lie with the focus on one UK-based industry, the extension of which could form the basis for further research. The uncertainty within the UK automotive industry over the past number of years has perhaps slowed down the uptake of Industry 4.0 across the sector. The issues surrounding semi-conductors are also likely to continue for several months, which again could slow down the uptake of Industry 4.0 and its associated technologies across the sector. Finally, there is the argument that as Industry 4.0 is just beginning to emerge within the UK automotive manufacturing sector it is perhaps still too early to validate any significant impact. The research findings are not generalisable to the whole of the UK automotive sector just the sample used for this research.

6.7.0 Potential Future Research

One of the potential opportunities for further study is to wait for a further two years or perhaps longer and conduct the same research on a much bigger sample within the UK automotive manufacturing. To determine why the future research should be delayed it is enough to look within the existing research. Although there was evidence suggesting around 13% are engaging within the research sample, it is still too early in the diffusion of Industry 4.0 within UK automotive manufacturing. Careful focus should be upon locating the right time to perform the research due to the delay between adoption and quantifying any impact of implementation efforts. Other factors might delay any future research due to the instability within the automotive sector caused by part shortages and where the efforts of many, as identified in the research, are focused upon managing this uncertainty.

To widen the sample, other possibilities could be to open the research to include other sectors such as aerospace, logistics and engineering. Comparisons could be made across sector to establish knowledge, adoption and impact patterns or more to the point, how other sectors have engaged with Industry 4.0. Such approaches could then be used as a basis to help organisational leaders engage smoother with Industry 4.0 in order to learn from what other have done and where they have failed. Arguably as automotive businesses are likely to engage more these types of industrial innovations, what will need to be considered is whether or not these engagement patterns are likely to occur within these other sectors.

Another interesting proposition for future research could be to study other automotive companies around Europe and to compare the findings. Such an approach could provide a wider and superior research sample encompassing other industrial sectors. Considering Industry 4.0 was a German-developed industrial strategy, it would be interesting to understand if or how German automotive companies are currently engaging. To consider this model with other European automotive manufacturing sectors would provide an interesting comparison to determine whether or not it is correct to suggest that the UK is being left behind in British industry’s quest for Industry 4.0 implementation.

6.8.0 Impact Plan

Academic Impact
- Brings an systematic approach in making sense of a complex phenomenon
- Conceptual framework has been used at conferences in clarifying Industry 4.0
- Clarifies the current level of awareness within UK automotive manufacturing
- Clarifies the rate of diffusion within UK automotive manufacturing
- Demonstrates the 'path' the early adopters have taken to engage with Industry 4.0
Career Impact
- It has generated an additional revenue stream for my business allowing the consultancy to grow
- Won work in the UK and US to help organisations engage with Industry 4.0 including a 12-month project secured in San Fransisco
- Asked to corroborate with a regional technology centre on digital readiness for the SME's, along with a government-funded initiative to assist the SME sector with digital engagement
- Discussion with investors regarding a new business venture around education 4.0, touching on three suites of modules which focus upon making sense of Industry 4.0, digital hard and soft skills. Looking to use gamification as the teaching pedagogy for the digital age
- Provides the researcher with options around career development
Personal Impact
- Explored areas of the brain which have not been explored before
- Built confidence in many areas which has changed the researcher's life
- Completely changed the researcher's view of bridging the gap between industry and academia
- Better informed about the right decisions through reading and knowledge development
- Allowed the researcher to develop a critical voice

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Appendix 1.0

Front-end base technologies. Cyber physical system and business needs added.

Smart Manufacturing	Smart Products	Business Needs
Technologies Vertical integration	**Technologies**	Creating the digital strategic vision
Sensors, actuators and Programmable Logic Controllers (PLC)	Product's autonomy	Voice of the customer
Supervisory Control and Data Acquisition (SCADA)	Product's optimization	Operational value stream transformation
Manufacturing Execution System (MES)	Product's control	Digital infrastructure
Enterprise Resource Planning (ERP)	Product's monitoring	Digital engagement
Machine-to-machine communication (M2M)	Product's connectivity	
Virtualization	Smart, connected products	
Virtual commissioning	**Smart Working**	
Simulation of processes	**Technologies**	
Artificial Intelligence for predictive maintenance	Collaborative robots	
Artificial Intelligence for planning of production	Augmented and virtual reality for product development	
Automation	Virtual reality for workers training	
Machine-to-machine communication (M2M)	Augmented reality for maintenance	
Robots (e.g. Industrial Robots, Autonomous Guided Vehicles, or similar)	Remote operation of production	
Automatic nonconformities identification in production	Remote monitoring of production	

Traceability	**Smart Supply Chain**	
Identification and traceability of raw materials	**Technologies**	
Identification and traceability of final products	Digital platforms with other company units	
Flexibility	Digital platforms with customers	
Additive manufacturing	Digital platforms with suppliers	
Flexible and autonomous lines	**Base Technologies**	
Energy management	**Cyber physical system**	
Energy efficiency monitoring system	Big Data	
Energy efficiency improving system	Cloud computing	
	Internet of things	
	Analytics	
(Frank et al., 2019)	(Frank et al., 2019)	

Appendix 1.1

Accenture - https://www.accenture.com/gb-en/services/industry-x-index

Atos - https://atos.net/en/solutions/industry-4-0-the-industrial-internet-of-things/industry4-0-exploration

Bain and Company - https://www.bain.com/search/?searchValue=industry+4.0

Boston Consulting Group - https://www.bcg.com/engb/capabilities/manufacturing/industry-4.0

Capgemini - https://www.capgemini.com/gb-en/resources/capgemini-innovationunleashed-2019-industry-4-0-and-innovation-in-the-digital-factory/

Convedo - https://www.convedo.com/digital-transformation-business-processautomation

Delta Capita - https://deltacapita.com/?s=Digital+Strategy

Deloitte - https://www2.deloitte.com/uk/en/insights/focus/industry-4-0/challenges-onpath-to-digital-transformation/summary.html

IBM - https://www.ibm.com/topics/industry-40?mhsrc=ibmsearch_a&mhq=industry%204.0

Hitachi Vantara - https://www.hitachivantara.com/en-us/searchresults.html?filter=0&q=industry%204.0

KMPG - https://home.kpmg/xx/en/home/campaigns/2018/11/industry-4-0.html

McKinsey and Co - https://www.mckinsey.com/business-functions/mckinsey-digital/howwe-help-clients

PWC - https://www.pwc.com/gx/en/industries/industry-4-0.html

Appendix 1.2

Automotive Manufacturing Solutions - https://www.automotivemanufacturingsolutions.com/technology

Digital Manufacturing Week - https://www.digital-manufacturingweek.com/event/de86a7e5-bba9-4cad-bde0-c2f3d3154613/summary?RefId=gsadmw&gclid=CjwKCAjwzaSLBhBJEiwAJSRokoeVkWpWOGrCrXV3iYRBrXUFY97xfkPElhgRaJKqEoSFI1Lje_UX1hoCWlcQAvD_BwE

Industry Week - https://www.industryweek.com/webinars/webinar/21177686/optimizingyour-business-operations-with-industrial-intelligent-edge-technologies

Industr - https://www.industr.com/en/digital-manufacturing-in-the-automotive-industry2607495

Manufacturing and Engineering Magazine - https://www.memuk.org/

Manufacturing Matters - https://www.manufacturing-matters.co.uk/?s=industry+4.0

Manufacturing and Production Engineering - https://mpemagazine.co.uk/?s=industry+4.0

New Manufacturing - https://newmanufacturing.co.uk/https://newmanufacturing.co.uk/

The Manufacturer - https://www.themanufacturer.com/articles/the-factory-of-the-futureis-here/

SMMT - https://www.smmt.co.uk/industry-topics/digital-manufacturing/

Today's Motor Vehicles - https://www.todaysmotorvehicles.com/magazine/

UK Manufacturing Online - https://www.uk-manufacturing-online.co.uk/?s=industry+4.0

Appendix 1.3 – Key Informants and Research Interviewees

Key Informant 1 – Academic

Key Informant 2 – Industry 4.0 and Lean Consultant

Key Informant 3 – Manager in an Automotive Trade Body

Research Interviewee 1 – Senior OEM Manager

Research Interviewee 2 – Senior OEM Engineering Manager

Research Interviewee 3 – Senior Maintenance Engineer Tier 1

Research Interviewee 4 – Senior Maintenance Engineer Tier 1

Research Interviewee 5 – Site Lean Lead Tier 1

Research Interviewee 6 – Senior Engineer OEM

Research Interviewee 7 – Consultant

Research Interviewee 8 – European Lean Lead Manufacturer

Research Interviewee 9 – Business Owner Tier 1