ROBOTICS AND THE LAW: EXPLORING THE RELATIONSHIP BETWEEN LAW AND TECHNOLOGY ADOPTION CHALLENGES IN THE CASE OF COLLABORATIVE INDUSTRIAL EMBODIED AUTONOMOUS SYSTEMS (COBOTS)

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Natalie Leesakul, LLM : *Robotics and the Law: Exploring the relationship between law and technology adoption challenges in the case of collaborative industrial embodied autonomous systems (Cobots)*.

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For my family,

and loved ones.

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ABSTRACT

The introduction of emerging robotic technology in manufacturing poses different legal issues from their predecessor of industrial robotics and automation where the separation between humans and machines is clearly visible. This new generation of industrial robots would allow for a more lean process and maximisation of efficiency at work. With human-robot collaboration, the advantages are the combination of high levels of accuracy, strength, precision, speed, endurance, and repeatability from the robot and the flexibility, sensitivity, creativity, and cognitive skills from the human.

To paint a picture, this emerging collaborative industrial embodied autonomous system (hereinafter referred to as "Cobot") explored in this thesis is often being referred to as robotic 'co-workers' in a popular culture. This notion is particularly important, despite its potential illegitimate claim, it establishes a position where this technology might find itself in the future of industrial workplace – being considered as another worker. Although manufacturing industry is no stranger to robotics, this emerging type of industrial robotics poses new challenges; identifying the relevant regulations is a challenge in itself.

This multidisciplinary thesis brings forward an integration of technology law, business management, and human-computer interaction (HCI) studies to explore Cobot adoption challenges and the role of law in addressing the challenges. This thesis approach to a socio-legal investigation of Cobot adoption is twofold: 1. Establishing the challenges through conducting exploratory research 2. Tackling legal challenges through conducting doctrinal research. It is vital for the exploratory research to be the first tier in order to explore concerns from different stakeholders. Thus, we interviewed 15 experts in relevant sectors to Cobot adoption and identified adoption challenges un-

der 10 themes: adoption of new technology, trust, risk, safety, due diligence, regulatory, ethics and social challenges, data & privacy, design, and insurance. In the doctrinal research, we investigated different legal doctrines in addressing safety, liability, data and privacy challenges found in the empirical studies which we concluded that the current regulatory frameworks are sufficient in responding to such challenges.

The novelty of this thesis is the findings from the orchestrating of a study to identify the challenges of Cobot adoption from multi-stakeholders' perspective and synthesize interdisciplinary material to present an elaborated landscape of Cobot adoption pain points. This thesis provides the breadth of the subject matter which has not been gathered before and the depth of specific regulatory responses to liability, safety, data protection and privacy challenges.

In this thesis, we made 5 contributions:

- Identified a gap in research and establish a new working term of Cobot (Chapter 2).
- Identified 10 adoption challenges based on empirical studies (Chapter 3).
- Created a framework for responsible Cobot adoption principles from multi-stakeholder's perspectives (Chapter 3).
- Presented a new perspective on Cobot regulations as a symbiotic relationship of safety, liability and data protection (Chapter 4).
- Provided recommendations and future research directions towards responsible Cobot adoption (Chapter 3, Chapter 4, Section 5.1.4 and Section 5.2).

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LIST OF ABBREVIATIONS

AI Artificial Intelligence
CSCW Computer-Supported Cooperative Work
CIS Collaborative Information Seeking
DMT Digital Manufacturing Technologies

DPIA	Data Protection Impact Assessment
HCI	Human-Computer Interaction
HRC	Human-Robot Collaboration
HRI	Human-Robot Interaction
IoT	Internet of Things
MWL	Mental Workload
RQ	Research Question
RSQ	Research Sub-question

LIST OF PUBLICATIONS, CONFERENCES, AND PUBLIC ENGAGEMENT

List of Publications

Parts of this thesis have been accepted by peer-review for publication in conference proceedings and journals:

- The empirical work presented in Chapter 3 and the Cobot adoption recommendations in Chapter 5 are published as:
  - Leesakul, N., Oostveen, A. M., Eimontaite, I., Wilson, M. L., and Hyde, R. (2022). 'Workplace 4.0: Exploring the Implications of Technology Adoption in Digital Manufacturing on a Sustainable Workforce'. *Sustainability*, 14(6), pp. 3311. DOI: 10.3390/su14063311

    This publication was in collaboration with DigiTOP researchers in exploring the potentials impact of DMTs on workforce and providing recommendations for industry on technology adoption. The findings of the empirical work contribute towards the understanding of building a resilience regulatory framework in supporting the sustainable and responsible Cobot adoption.
- Other contributions relating to the work conducted in this PhD thesis are published as:
  - Urquhart, L., Reedman-Flint, D. and Leesakul, N. (2019), 'Responsible domestic robotics: exploring ethical implications of robots in the home'. *Journal of Information, Communication and Ethics in Society*, Vol. 17 No. 2, pp. 246-272. DOI: 10.1108/JICES-12-2018-0096

My contribution in this publication is based on the work conducted as part of the findings in Chapter 2 and Chapter 4

– Mase, J. M., Leesakul, N., Figueredo, G. P., and Torres, M. T. (2022)'Facial identity protection using deep learning technologies: an application in affective computing'. *AI Ethics*. DOI: 10.1007/s43681-022-00215-y

  My contribution in this publication is based on the work conducted as part of Chapter 4

– Neu, C.V., Gibson, J., Lunardi, R.C., Leesakul, N., Morisset, C. (2023). 'A Blockchain-Based Architecture to Manage User Privacy Preferences on Smart Shared Spaces Privately'.In: *Garcia-Alfaro, J., Navarro-Arribas, G., Dragoni, N. (eds) Data Privacy Management, Cryptocurrencies and Blockchain Technology*. DPM CBT 2022 2022. Lecture Notes in Computer Science, vol 13619. DOI: 10.1007/978-3-031-25734-6_9

  My contribution in this publication is based on the work conducted as part of Chapter 4

– (Forthcoming - Accepted) Leesakul, N., Morisset. C., 'Position Paper: The role of law in achieving privacy and security measures in smart buildings from the GDPR context' In: *the 13th International Workshop on Socio-Technical Aspects in Security* the IEEE European Symposium on Security and Privacy'23

  This publication is based on the work conducted as part of Chapter 4.

Conferences, Workshops, and Public Engagement

This PhD has resulted in multiple knowledge exchange opportunities to engage with the wider community and raise awareness on the importance of socio-legal research in technology adoption. Active participation in conferences, workshops, research projects, and public engagement activities has had a substantial impact on shaping the direction and narrative of this PhD. We have curated a selection of relevant works, which are provided in the list below.

- Part-time research associate at the Newcastle University where I applied this PhD thesis findings on Cobot in a wider context of human-machine interaction from the perspective of legal challenges of a socio-technical system of smart connect spaces. Date: January 2021 to July 2023
- Six-month internship with Innovate UK under Made Smarter Innovation (MSI) Challenge team where I had the opportunity to engage with UK manufacturers, policy makers in manufacturing sector, and academics in this niche area of research. Through participating in events, workshops, and team activities in funding emerging manufacturing technology projects, this has broaden my understanding of the sector and the maturity of my knowledge to reflect on this thesis. Date: September 2021 to February 2022.
- Invited Speaker, Manufacturing & Engineering Week 2023 on the topic of The future of Jobs: How young academics are shaping the future of manufacturing. Date: 8 June 2023. See here
- Developed and helped running DigiTOP workshop on robot and data ethics content as part of educational set of resources on the introduction to digital manufacturing technologies (DMTs) aimed for a younger audience. This public engagement activity helped shape my understanding of the topic and contribute my research findings to to a wider here I contribute to the development the PhD thesis
- Invited Speaker, at UKRI Trustworthy Autonomous Systems Hub DTN seminar. Date: 30 March 2021 See here
- Invited Speaker, Ada, the National College of Digital Skills on the topic of AI Governance and Human-centre AI including

my research on responsible adoption of autonomous systems in the workplace to students in an apprenticeship program (3-year BAC equivalent). Date: 6 January 2021.

- Abstract accepted unpacking Cobots in the context of due diligence at Bileta Conference, Tilburg (April 7-8th 2020) (conference cancelled due to COVID-19 pandemic)

- Presented the PhD findings at DigiTOP project retreat where I also obtained extensive feedback and inputs from the industry partners (BAE, BSI, Jaguar, Babcock, MTC) on Cobot adoption challenges which helped shape my arguments in Chapter 3 on February 6-7, 2020.

- Invited Speaker, at 'What legal principles govern accidents involving autonomous vehicles: The Automated and Electric Vehicles Act 2018 and beyond' seminar, University of Nottingham Commercial Law Centre, with Professor Richard Hyde, on the topic of the technology landscape of autonomous systems. Date: 13 November 2019 See here

- Invited Speaker, at Robotics, AI and ethics seminar, University of Loughborough, led by Professor Ella-Mae Hubbard where I introduced my research in . Date: 11 June 2019

- Poster presentation on the topic of the role of law in Cobot adoption, at PACTMAN: Trust, Privacy and Consent in Future Pervasive Environments Symposium, Edinburgh. Date: 10-11 December 2018

- Presented 'Responsible domestic robotics: exploring ethical implications of robots in the home' paper, at ETHICOMP conference. Date: 24-26 September 2018.

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1

INTRODUCTION

Robots as co-workers, are WE ready for it?

Regulators, designers, business operators, workers, collectively as 'WE'

Contents

1.1 BACKGROUND AND MOTIVATIONS

1.1.1 *The Big Picture: Collaborative Industrial Embodied Autonomous Systems ("Cobots") in Industry 4.0*

The Fourth Industrial Revolution[1], or Industry 4.0, marks the period of transformation to digital manufacturing[2] in which industrial machines are digitally connected with one another, enabling them to share data and making autonomous decisions (Thoben et al., 2017). This movement signifies the new industrial environment where emerging technologies, also categorized as digital manufacturing technologies (DMT), are introduced to support manufacturing operation; some of the examples are Internet of Things (IoT), Augmented Reality (AR) , cloud computing, advanced robotics, big data analytics and digital twin. Furthermore, legacy machines are also integrated with computational systems to help analyse their performance and the current production process to better understand productivity and efficiency, including identification of bottleneck areas (Ghobakhloo, 2018). This wave of technological innovation will enable organizations to strengthen their competitive advantage by fundamentally reconfiguring their business operations in order to improve productivity, reduce risks, and increase product quality and customisation ability (Moktadir et al., 2018). Because despite best efforts to fully automate the production lines, it is clear that at present, there needs to be a human element to manufacturing. Take the recent example of Tesla's issues (Lanteri, 2021) in trying to fully automate their manufacturing,

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1 The first industrial revolution was sparked by the invention of the steam engine; the second by the adoption of mass production technologies and methods to produce steel and organic compounds; and the third by the adoption of digital technologies, such a computer-aided design.

2 Digital manufacturing is an approach enabled by smart factory; though these 2 terms are often used in the same context by the industry as a smart factory infer a space which supports digital manufacturing approach. For further explanation on 'digital manufacturing' see (Van den Bossche et al., 2016).

which resulted in significant delays in production and the need to re-engineer the factory multiple times. Machines still cannot easily deal with the complexity and variations that arise during the manufacturing process; therefore, human intervention will remain essential to the advancement of manufacturing sector.

Consequently, achieving the potential integration of Industry 4.0 will require manufacturers[3] to move towards more of human-machine collaborations to augment human workers' capability and improve safety from wearable technologies[4] in training and maintenance work to exoskeletons to enhance operator's physical strength. Although manufacturing process is already assisted by automation, in many sectors, human-led production lines still dominate. However, this often results in human workers take on mundane and repetitive tasks which can lead to physical injury and absences over time, causing higher costs and lower productivity (Bevan et al., 2009). With the progress towards human-machine collaboration, the new generation of connected machines can help; putting less physical burden on human workers whilst assisting in decision-making processes. In particular, these goals can be achieved through emerging digital manufacturing technology, in particular, the introduction of **collaborative industrial embodied autonomous systems ("Cobots")**[5].

3 Manufacturers referred to in this PhD thesis is in the view of robot adopter as opposed to robot manufacturers. We recognised that this could be confusing as the robot manufacturers also have certain associated risks and liability in supplying robots, however, in this PhD thesis context, we focused on adoption barriers. Therefore, when referring to the provider or the maker of the robots, we consider this group of stakeholder as technology designer or developer.

4 For example, Google glass and Microsoft HoloLens can be used for hands-free training in job site. Operators can have access to information right in front of the eyes and can also interact with the digital replica of the machines.

5 The term Cobots is still at debate which will be unpacked further in Chapter 2 Cobots in majority of literature stands for collaborative robotics in a form of robotics arm. However, over the past 4 years, we have come across other types of industrial robots that are not robotic arms but have similar characteristics that should be classified as collaborative robotics in which they are designed to operate around human workers, leading to the term industrial collaborative embodied autonomous systems

Figure 1.1: Traditional Industrial Robot

Manufacturers are no strangers to robotics. Robots were introduced to manufacturing in the 1950s (Wallen, 2008). However, automated tasks performed by industrial robots are clearly sectioned from human-led processes due to safety concerns (see Figure 1.1[6] below). The tasks performed by traditional industrial robots are typically specific and scripted activities, resulting in a rigid production line.

However, Cobots are different. They redefine the common perception of industrial robots of being dangerous and dull – paving a way for more human-centric robotics design in manufacturing (Hentout et al., 2019). Cobots are meant to be human helpers, coining the term **robot co-worker**, as they are designed to work alongside humans and in the long term be more adaptable to change including high agility and flexibility when requires performing under open-ended commands or tasks. Cobots, at the fundamental level, are more akin

as a focus of this thesis. Therefore, to set the scene for the subject matter, we deliberately describe Cobots as collaborative industrial embodied autonomous systems given its underlying characteristics and purpose. Consequently, we want to focus on the aspect of embodied autonomous systems as this will help set the scope of relevant legal framework such as EU AI Act considering that Cobots are a form of embodied AI in which allows for human-robot collaboration as see in (Vanderborght, 2019)

6 The image is from https://www.theguardian.com/business/2019/sep/18/uk-economy-has-too-few-robots-warn-mps

Figure 1.2: Rethink Robotics Baxter - collaborative robotics

to domestic robots than traditional industrial robots that are a programmed task-specific machine. The design of this technology directs towards usability factors with the ability to better communicate with human workers in a more naturalistic way such as the display of facial expression in the example of Figure 1.2[7] or designed to be more lifelike mirroring an organism for higher level of agility like Figure 1.3[8]. Although some of the Cobots may look similar to industrial robotic arms, they can operate safely without being kept in a cage or sectioned away from human workers. Thus, the adaptability and safety of Cobots allow for a faster reconfiguration of the production line to support the demands of new products which can help improve efficiency and decrease downtime in manufacturing sector.

Overall, Cobots and other DMT are intended to be a complementary tool to human workers as opposed to a substitution of human input. At least, that is the goal. To achieve this objective, we need to ensure the impact of the transition to digital manufacturing technologies are considered and mitigated. Whilst disruptive technology will nonetheless replace some tasks but will also create new ones. To state the obvious, job displacement is one of the major discussions in

7 The image is from https://spectrum.ieee.org/spots-new-upgrades-bring-enhanced-autonomy-payload-integration-and-stair-smarts

8 The image is from photo credit: https://spectrum.ieee.org/spots-new-upgrades-bring-enhanced-autonomy-payload-integration-and-stair-smarts

Figure 1.3: Boston Dynamics Spot

relation to technology adoption. With human-machine collaboration, other issues, such as liability, safety, and privacy, are also frequently brought up and the answers to such concerns remain unclear. Inevitably, technology will transform the traditional workplace and how people work, the question lies 'will this transformation require an updated regulatory regime to support the unprecedented interaction between human and machines in industrial workplace'?

1.1.2 *Regulating Cobots*

DMT are here to stay and support production line. However, invention of disruptive technology comes with certain challenges that the regulators have not previously grappled with. For example, the internet has changed how we buy and sell things (Savin, 2017). E-commerce challenges various regulatory frameworks from consumer protections to contract to data protection and privacy. As addressed in the background above, DMT are enablers for Industry 4.0 but some of these emerging technologies are completely new to industrial environment. Despite the promising benefits, there are various organisational constraints, such as, financial capability, IT maturity, and knowledge competencies (Ghobakhloo, 2018) that need to be overcome to support the transition to Industry 4.0. For example, firms will need to consider different strategies to gain employees' acceptance of the new shift into workspaces with a high level of complexity and automation. Human workers will need to adapt and learn to work in conjunction with advanced robots; the challenge will also be around how to manage human resources and increase worker skillsets while ensuring the retention of jobs given the change in working environments (Hecklau et al., 2016a). Furthermore, data security issues must be considered given the integration of multiple digital technologies creates a new ecosystem in which requires continuously data sharing between software and hardware designed different suppliers.

These new challenges will continue to emerge alongside Industry 4.0. As Industry 4.0 introduces novel technology, new products, services, and business models, transpire where law and policy will need to be reshaped to help stimulate innovation as well as protect people because the existing regulatory systems are being challenged. This is recognised at the government level which demonstrates that Industry 4.0 will be a long-term transition and regulatory response is required given the novelty of this transition. In 2019, the UK government published a policy paper "Regulation for the Fourth Industrial Revolution" (Secretary of State for Business and Strategy, 2019).

This policy is part of the UK Industrial Strategy (GOV.UK, 2017), yet another indication that Industry 4.0 will continue to advance and gain more momentum with government support. This proposal is to be a viewed as a response to the technological change to ensure that the regulatory system keeps pace and aims to address obstacles businesses may face in bringing forward new propositions for industrial transformation while ensuring the balance benefits for its citizen. Thus, the proposal focuses on the outcome approach in order to "develop an agile regulatory approach that supports innovation and protects citizens and the environment." Balancing the interests of different stakeholders in technology adoption is certainly the holy grail, but the route to achieve this objective is not so clear. This ambitious overarching policy include, but not limited to, the followings (Secretary of State for Business and Strategy, 2019):

"Creating greater space for experimentation to support and stimulate new products, services and business models

- *Upholding safeguards for people and the environment and engaging the public in how innovation is regulated*
- *Piloting an innovation test so that the impact of legislation on innovation is considered during the development of policy, introduction and implementation of legislation and its evaluation and review.*
- *Ensuring that innovators have confidence in how government is developing new legislation*
- *Developing tools for regulators to support them to review their guidance, codes of practice and other regulatory mechanisms to ensure that they provide flexibility for those businesses that want to innovate, while ensuring a clear route to compliance.*
- *Supporting business, policymakers and regulators to make effective use of standards where appropriate as a complement to legislation.*
- *Establishing a Regulatory Horizons Council to identify the implications of technological innovation and advise the government on regulatory reform needed to support its rapid and safe introduction"*

On this basis, despite the regulatory objective to ensure the balance of business incentives and protection of the public, the listed goals appear to be heavily focused on innovation stimulation and adoption. Consequently, although the overarching motive of this proposal is to focus on the outcome, however, it does not address further on the targeted outcomes and how to achieve such outcomes. Although it is recognized that regulatory requirements will need to be updated in order to support the industrial transformation, there is still a lack of clear guidelines on what that regulations will look like based on the desired outcomes in considerations for all stakeholders. We consider that the Regulations for the Fourth Industrial Revolution is a proposed policy and therefore it merely outlines the desirable outcomes. Thus, there is a lot of room to shape policy. However, this is also a limitation for the research given the lack of concrete regulatory frameworks.

Furthermore, with digitalisation and human-robot collaboration, we see that the lines are blurred between sectors and traditional regulatory boundaries. With Cobot adoption, manufacturers will need to consider different legal issues from their predecessor who dealt with industrial robotics. Although robotics in manufacturing is heavily regulated, it is important to question whether the current standards are appropriate to govern the implementation of Cobots. There are strict policies on safety protocols, such as, physical barriers, sensors, and other systems to prevent people from being in close proximity to the robot while it's working and to ensure that the robot automatically stops when people are within certain range; isolating Cobots in cages will entirely defeat the purpose of this technology. The safety challenges with Cobots cannot be overcome by simply installing standard movement detection; the autonomous aspect of Cobots requires additional safety standards for decision-making criteria programmed into robots.

As Cobots learn from human workers, the system must enable robots to distinguish desirable behaviours from harmful behaviours so that a robot can only replicate the desirable human behaviours (Burke et al., 2006). Consequently, the interactions between Cobots and humans can create the norms of endless personal data collection and processing which can have an implication on the principle of privacy and data protection. Manufacturers will need to provide safeguards to ensure that any personal data captured by a robot is processed in compliance with data protection laws. Employees may also feel that they are under surveillance when interacting with technologies that have sensors such as cameras and microphones. Manufacturers will need to rethink about their data control policy. In some cases, a robotics company may request data collected by robots, for example, to collect robot performance feedback and for maintenance purposes. This may be problematic, as besides personal data, there are also commercial sensitive data. Therefore, how can manufacturers and employees be confident that their data are protected. Adding to the mix of cobot providers, the robot's software may rely on cloud computing storage in another suppliers database so this could trigger a chain of contractual agreement on complicated data sharing.

Liability is another key challenge with embodied autonomous systems as we also see similarity in connected-autonomous vehicles (CAVs).[9] For example, a form of services can be licensing a cobot software to cobot hardware company who then lease the robots to manufacturers. In this scenario alone, from different point of connections, there are various legal concerns that need to be address: who is liable if a robot hurt somebody? The production line manager who works with the robot? The robot software provider? The robot companies? The answer will always be "it depends."

In order to respond and adequately direct the trajectory of Industry 4.0, a collective effort will be required to navigate the challenges around the DMTs adoption. Human plus machine may be the best direction of travel; as Cobots are unique given that they are embodied autonomous systems, the magnitude of harm it can caused is certainly at a higher risk than other DMTs. Right now, Cobots still face technological constraints in achieving the ability to fully collaborate with humans but providing that this technology is part of the Industry 4.0 movement, as we have already demonstrated, Cobots are here to stay. Cobots will continue to challenge the current legal landscape as the technology matures. In regulating emerging technology, we acknowledged Collingridge's argument on the dilemma in taking the predictionist approach to govern undesirable innovation as a "serious misconception[s]" since "harmful effects of a technology

9 In the UK see, for example, the Automated and Electrical Vehicles Act 2018.

can be identified only after it has been developed and has diffused" (Liebert and J. C. Schmidt, 2010). We recognised that as with every technology, it is difficult to cover all corners, given that the impacts will depend on how technology will be used, who will use it and for what purpose. For example, social media presents benefits, such as, access to information and increase social connection, but it has later been realised that such platform can become a new avenue for harassment known as cyberbullying (C. Wilson and Stock, 2021). Could have this been prevented? To Collingride's argument, "a key obstacle to dealing with science and technology in society is the lack of knowledge about consequences during the early phases," however, Liebert and Schmidt interpreted this argument as "the dilemma presupposes a strong demand for adequate knowledge" (Liebert and J. C. Schmidt, 2010). Therefore, since cobot development is still at the nascent stage, we need to move towards understanding the challenges and forming adequate knowledge **now** in order to determine what the ideal adoption outcomes should look and prepare for the future adoption.

1.1.3 *So, Now What?*

Conversation about regulating robots is not new and has been a hot topic in the recent past (Calo et al., 2016). One of the most prominent interventions on regulating robots is the European Parliament resolution of 16 February 2017 with recommendations to the Commission on Civil Law Rules on Robotics (2015/2103(INL)) discussing the issues surrounding but not limited to robot liability, use of personal data, and robots as legal personalities (Nevejans, 2016). This recommendation has paved a way to further development on the attempt to regulate robots and AI in all sectors. This thesis investigates Cobot adoption because the trend of Industry 4.0 establishes a promising ground for Cobots and giving the technology validity however there is a research gap on understanding the impact. At the start of this thesis in 2018, the literature exploring legal, ethical, and social challenges of cobot adoptions was limited with the premise that industrial robots are often overlooked since manufacturing sectors are already highly familiar with the robotics unlike in other environment such as public space, home, or hospital. In 2020, we started to see more attention drawing towards Cobots in an article published by Studley and Winfield, calling for more research on the implications of Cobots (Winfield et al., 2021). We see that Industry 4.0 presents new challenges demanding for the regulatory systems to adapt; Cobots, as part of this environment, will have to adhere to both the industry wide regulation and also specific regulations in relations to autonomous systems and industrial machinery.

Returning to the very first question we posed at by this thesis,*"Robots as co-workers, are we ready for it?"* This question situates the two prominent themes that will recur throughout the thesis. For the first theme, whilst a robot as a co-worker may sound far-fetched; this demonstrates potential new challenges arise with cobot adoption of which we may not have thought of when dealing with industrial machinery. For example, although most likely a public relations stunt, Saudi Arabia granted a citizenship to a social robot Sophia in 2017 (Griffin, 2017). This thesis calls attention to expecting unexpected outcomes. Although humanisation of robots is an implausible claim (for now), this event brings attention to debates on future robotics' regulations, which we will explore in the following chapters. In the second theme, the thesis examines regulators, designers, business operators, workers, collectively referred to as 'WE.' This highlights the importance of multistakeholder perspectives in preparing for cobot adoption. It will require a whole ecosystem consisting of different factors from law to business readiness to policy to the technologist to the end users, setting an agenda for multidisciplinary research.

Furthermore, we are motivated by the human-robot collaboration because this is a completely new concept to traditional manufacturing sectors given its potential to change the current relationship between shop floor workers and the machines. Industrial robots and people should never mix, at least according to existing health and safety regulation, meanwhile, Cobots are meant to do just that. Cobots will operate and, to the extent, collaborate with human workers; therefore, making a case for a novel research topic. Furthermore, the manufacturing sector has dealt with controversial debate on technology to help combat skills shortage and aging workforce versus job displacement due to the use of technology; whilst DMT including Cobots support the former as it symbolizes the move towards human-machine collaboration there is still an unknown territory that needs to be explored to ensure that the repercussions from technology adoption are managed.

Therefore, we want this thesis to be a medium in bringing different perspectives together to prepare and be *ready* for the future of cobot adoption. Hence, the *objective* of this PhD is to address the regulatory implications and challenges posed by the adoption of collaborative industrial embodied autonomous systems Cobots. By looking into the adoption challenges from a multi-stakeholders perspective, we will be in a better position to explore the gap between "law in the books" and "law in action" (Banakar and Travers, 2005; Chui and McConville, 2007) within the context of digital manufacturing, and provide appropriate recommendations to policymakers and businesses.

1.2 RESEARCH QUESTION AND METHODOLOGY

1.2.1 *Research Question*

In navigating the ambiguity of legal landscape of Cobots with an attempt to explore the challenges and solutions, the main research question Research Question (RQ) is

"To what extent can the law address the adoption challenges raised by collaborative industrial embodied autonomous systems (Cobots)?"

To answer this key question, we broke down the thesis into 3 research subquestions Research Sub-question (RSQ) which dictate how the thesis is organised for the following reasons:

- RSQ1. What are Cobots in the context of Industry 4.0 and the current regulatory landscape?

  Rationale: This question is to establish the subject matter. We first need to explore what is the technology we want to regulate in detail as it is important to understand the technology as well its limitations. We also need to examine the current landscape of robot regulatory approaches to develop a more comprehensive literature review on cobot and the law.

- RSQ2. What are the legal, ethical, social and organisational challenges and implications of Cobot adoption in digital manufacturing?

  Rationale: Once we have established what is a cobot, we need to investigate the impact and challenges of such technology in order to understand to how can the current regulatory systems respond to and support Cobot adoption specifically in a digital manufacturing environment.

- RSQ3. How can the law respond to the challenges found from RSQ2?

  Rationale: As we arrive to RSQ3, we have already established the subject matter and the challenges and implications of cobot adoption. This question will lead the legal analysis, which will prompt the answer to the overarching question.

We purposely designed the research sub-questions to follow the previous findings given the nature of the research topic. The purpose of each research sub-question RSQ is to guide the 3-part analysis to build a foundation on the subject matter before proceeding to the recommendation in responding the main research question.

1.2.2 *Methodology*

The research sub-questions are developed to investigate the regulatory implications and challenges posed by the adoption of collaborative industrial embodied autonomous systems ("Cobots"). To achieve this objective, a multidisciplinary research approach is taken. This PhD follows a socio-legal research approach which is a combination of doctrinal research and empirical research to understand the current legal frameworks and the pressing legal, ethical, and social concerns from the industry within the context Cobots in digital manufacturing (Chui and McConville, 2007; Banakar and Travers, 2005).

By taking on a social-legal research methodology, this thesis tackles the main research question and sub-questions with technology law at the foundation, applying social science methods and knowledge from the field of computer science and engineering to understand the advancement in the design of technology and the progression of Cobots. Due to the criticism towards the mismatch or slow development of regulation in relation to technology, it is required that the definition of cobot and its technology advancement including the potential capability is discussed on the basis on current state of the art as well as the future of Cobots (i.e., speculative technology). This is highlighted by Ballard and Calo, who argue that it is important to think about the future of the technology because "in failing to consider the future of technology, we are often left with laws and policies that fall short of our technological reality" (Ballard and Calo, 2019). Therefore, a definition of the subject matter is highly important in conducting the legal analysis and it needs to be established both where Cobot technology is and where it could be. Therefore, we analyse Cobots based both on their current form and potential future form. Moreover, traditional doctoral research in analysing black letter law often engages in legal analysis in the light of existing case law, but this is often challenging in the case of disruptive innovations such as Cobots, and therefore it is necessary to analyse how case law will apply to the future forms of such innovations.

Accordingly, a lack of literature in the space of Cobots from a legal perspective might lead to a far-removed analyses from what is happening in practice. Facing with this limitation, social science research methods are required in exploring the topic. Therefore, we conducted semi-structured interviews analysed by thematic analysis to investigate the challenges from the practice perspective from professionals who are knowledgeable in technology adoption, particular autonomous systems, to gain realistic analysis of the current circumstances (Afolayan and Oniyinde, 2019; Braun and Clarke, 2012). We found expert interview method to be most appropriate to gain industry insights (see Chapter 3) and understand the challenges from the perspectives of experts ranging from manufacturers to lawyers to consultants to technologists with most of the experts having more than 15+ years of experience in the field relevant to technology adoption. To ensure rigorousness of the findings, we collaborate with our research partner, DigiTOP, (see Section 1.4.2) to conduct a survey (in Section 3.2.2 to understand border stakeholders' perspectives in particular end-users (i.e., manufacturing employees); the analysis is supported by colleagues who are expert in quantitative analysis providing that this is not our field of expertise. Ultimately, following the theme highlighted in Section 1.1.3, it is mandate for *WE – the end users, technologists, and law enforcers* to collaborate in order to effectively tackle regulatory challenges.

Consequently, the doctrinal research is dedicated to examining the findings from the empirical study and therefore provide adequate knowledge of the subject matter. The legal analysis considers frameworks and legal literature from different jurisdictions (predominantly UK and EU) given the emerging nature of regulatory development in this area. However, a comparative study of different regulations is not within the scope of this PhD thesis. The primary objective here is to comprehensively explore the intricate relationship between law and technology through any available means. We analyse the current regulatory frameworks and case law in relation to the challenges found in the empirical study to examine whether the application of law needs to be better applied to cope with the technological change, or that we need new law, or whether we need different regulatory instruments altogether. In conducting doctrinal research, we take on the robot law outlook because the field deals with scrutiny over current legal regime and its applicability to the emerging field of robotics while exploring how emerging robotics technology poses or threatens the legal system and proposing novel legal approach to regulate. Robotics is a wide-ranging field; Leenes and others considered this field to have a characteristic of "technological products display some level of autonomy in their functioning, which is a new edge to interaction between humans and technology" (Leenes et al., 2017a). By this definition, the legal concerns of Cobots found in the empirical study are discussed in the light of regulation of robotics in general as there appears to be limited literature in the specific area of the law and Cobots.

Given the nature of this PhD topic, the literature review comprises of academic peer-reviewed articles, grey literature, industry report and standards, white papers, and legal frameworks. To exemplify the current state of the art of Cobots, we include commercial products, academic projects, and governmental programmes. In legal discussion, we are particularly interested in WeRobot Conference and consider the papers accepted to this conference to be a scholarly source even though there is not a formal conference proceeding publication. The conference has a rigorous evaluation of paper submissions, and the venue encourages new perspectives on AI and robot regulations; therefore, we find the conference papers to be highly applicable to this thesis. Furthermore, as the discussion on the impacts of Cobots in the academic papers is still at a developing stage, we consider a wider range of sources involving industry discussions such as blogs, new articles, discussion forums, and company's research reports. We acknowledge the potential risks of grey literature given the prospective hidden agenda and commercial interest. Therefore, this limitation is considered throughout the analysis and the sources are treated with greater cautious and carefully deliberate before implementing in the thesis.

In conclusion, we undertook a socio-legal research approach to answer to the research sub-questions. The literature review establishes the premises of Cobots in digital manufacturing. The empirical study constructs the parameters of the challenges and implications of Cobot adoption. The doctrinal research informs the readiness of the regulatory systems in directing disruptive technology adoption. The steps taken as demonstrated in our methodology are the building blocks to answering the overarching research question (RQ) of "to what extent the law address the adoption challenges raised by collaborative industrial embodied autonomous systems (Cobots)?"

1.3 RESEARCH AREAS

As this thesis explores a multidisciplinary research topic, the research overlays across different disciplines. We draw together principles from human factors, computer science, business, and law as we find that these research areas are particularly salient to the successful adoption of Cobots. Certainly, the design aspects including human-robot interaction HRI are also vital, however, these aspects are also considered within human factors. Consequently, as we have identified in Section 1.1.2, the UK government recognises a strong correlation between regulations and innovation given the importance of regulatory systems in supporting businesses and stimulating technology adoption. Thus, strategic management methods must be considered to ensure industry applicability. Furthermore, it is acknowledged that the law is not the only regulatory instrument applicable to technology governance as we have seen in the work established under cyberlaw. To conceptualise this intertwined relationship between the role of law

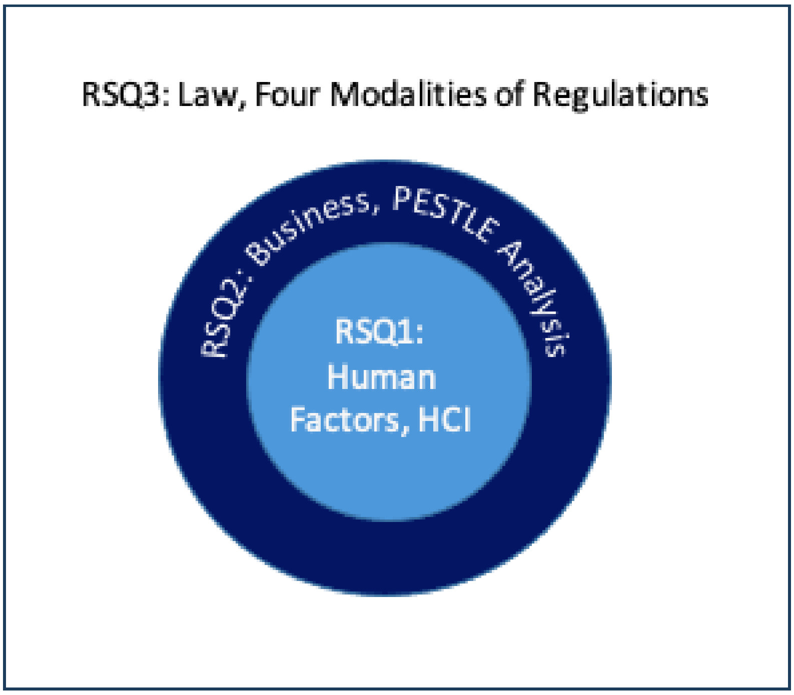

Figure 1.4: Thesis Framework

and technology adoption and their influences over one another attributing to the multidisciplinary of this thesis, we illustrate in a diagram below.

The thesis framework demonstrates the synthesis of different frameworks including, but not limited to, 'Method in the Understanding of Human Factors' (Figure 1.5), PESTLE Analysis (Figure 1.6), and Four Modalities of Regulations. It should be noted that there are elements of the disciplines cutting across the research sub-questions and chapters, however, the thesis framework is used as a guideline to structure the multidisciplinary nature of this thesis. The layers are correspondent to research disciplines and the research sub-questions (RSQ) indicated in Section 1.2.1:

- Human factors and HCI: RSQ1. What are Cobots in the context of Industry 4.0 and the current regulatory landscape?
- Business: RSQ2. What are the legal, ethical, social and organisational challenges and implications of Cobot adoption in digital manufacturing?

- Law: RSQ3. How can the law respond to the challenges found from RSQ2?

1.3.1 *Human Factors and Human-Computer Interaction*

With Cobots, human factors and Human-Computer Interaction HCI will form the core of technology adoption. We have highlighted in Section 1.1 on how technology is here to support; on that account, understanding how humans and machines interact and work together will inform the role of Cobots and the potential challenges of such adoption as we have seen in the previous industrial transformation known as the ironies of automation whereby automation of industrial processes could expand rather than eliminate problems with the human operators. This notion was introduced by Bainbridge in early 1980s to capture the phenomena of 'tasks after automation' – the need for human operators to maintain, monitor, or override the system to ensure that it working efficiently even though automatic control system has been put in because it is supposed to do the job better than the operator (Bainbridge, 1983). However, human operators may face challenges when a manual take-over is required. For example, human operators can only generate successful new strategies for unusual situations if they have an adequate knowledge of the process; this knowledge is only developed through frequency of use and feedback about its effectiveness which in the case of automation, human workers are not actively engaging with the process. We saw this in 2009 in the case where the pilots of Air France Flight 447 failed to appropriately control the plane and crashed into the ocean off the coast of Brazil, killing 216 passengers and 12 crew members (Geiselman et al., 2013). The crash demonstrated the ironies of automation in twofold: the manual take-over took the pilots by surprise and the pilots' unfamiliarity with the system due the lack of frequent engagement with the system. Providing this background, it is crucial that organisations understand the challenges of Cobot adoption in relation to human factors and human-computer interaction.

Consequently, technology adoption is not happening in silo where it is only about putting people and Cobots together as such interaction is equally subjected to the influence of other factors. Wilson and Sharples address this foundation in their 'Method in the Understanding of Human Factors framework' which they refer to as the 'onion model' (J. R. Wilson and Sharples, 2015). The framework (Figure 1.5 presents the layers of the interactions of factors that are relevant to the field of ergonomics and human factors. At the centre, the focus is on the people, technologies, and artefacts placed within the wider context of tasks, workspace and organisational level that are influenced by financial, technical, social and legal considerations. The onion model inspires how this thesis unfolds. We start by establishing the foundation of human-robot collaboration then working our way towards understanding the challenges and the influence of law on the adoption. All these elements must come together to establish a policy driven user-centric approach for human-robot collaboration.

1.3.2 *Business*

Given the objective of this thesis, industry perspective is crucial to unpack the adoption challenges and to what extend can the law support such transformation. PESTLE Analysis is one of the derivatives of PEST, a method is widely adopted by industry as part of strategic thinking approaches in order to evaluate the risks and potential issues of the project given the impacts of 6 key factors: Political, Economical, Social, Technical, Environmental, and Legal influences. In the work by Sammut-Bonnici and Galea (see Figure 1.6), PESTLE is a common evaluation tool often used in conjunction with the Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis and Porter's five forces model to help businesses evaluate their competitive positions and mitigate the effects of external factors through pre-emptive strategies

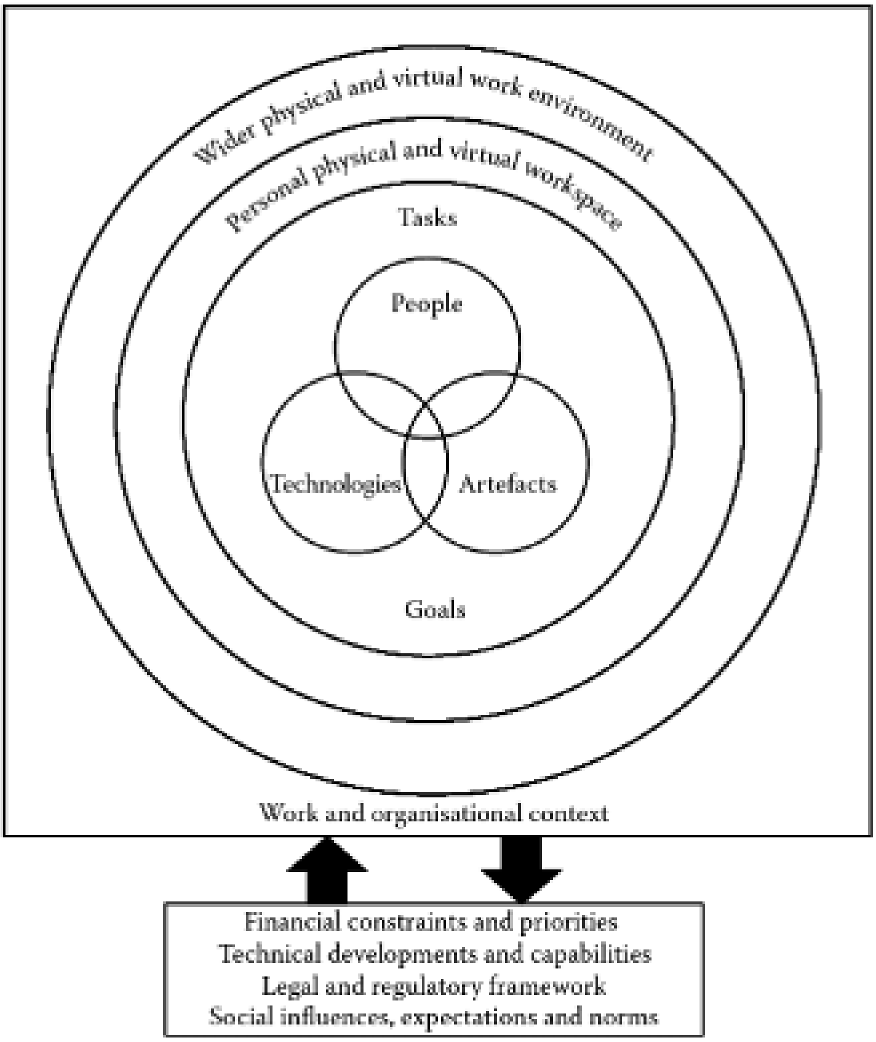

Figure 1.5: The Onion Model. The illustration is from (J. R. Wilson and Sharples, 2015, p. 10)

(Sammut-Bonnici and Galea, 2014). This big picture approach underlines how the external influences can have a major impact on businesses' ability to thrive in the market. Applying this analogy to Cobot adoption, Cobots, as part of disruptive Industry 4.0 technology, are transforming the way of work; thus, human-robot collaboration is formed as part of industrial strategy. For businesses to adopt this technology, they will need to consider the influences of external factors that may hinder, interfere, or enhance the business. Therefore, we use this model as a guide to establish the baseline of RSQ2. In gaining industry's input through the empirical research, we focus on capturing the social and legal implication and challenges Cobots as these elements will be used to form the basis of RSQ3. Consequently, these factors are also aligned with Wilson and Sharples' framework, hence, these allow us to maintain a coherent narrative and synthesise the two models into the thesis framework (see Figure 1.4). We recognise that there are other existing tools to assess technology adoption challenges, such as Technology Acceptance Model (TAM) (Burton-Jones and Hubona, 2006). However, we find that TAM and its extensions and adaptations (e.g., TAM2, UTAUT) do not capture the full landscape of technology adoption as they focus on people's intentions to adopt a technology based on its perceived usefulness and ease of use. Therefore, PESTLE approach brings together the key elements that this PhD aligns to given that it concentrates on the wider considerations that can impact technology adoption including regulations.

1.3.3 *Law*

We have discussed in Section 1.1 on the role of law in driving innovation. The law has the power to galvanize or stifle technology advancement and adoption, therefore, the law is a form of constraints as it regulates on what businesses can and cannot do. However, the law is not the only constraints on technology as we already see in the onion model and PESTLE Analysis that there are factors that can in-

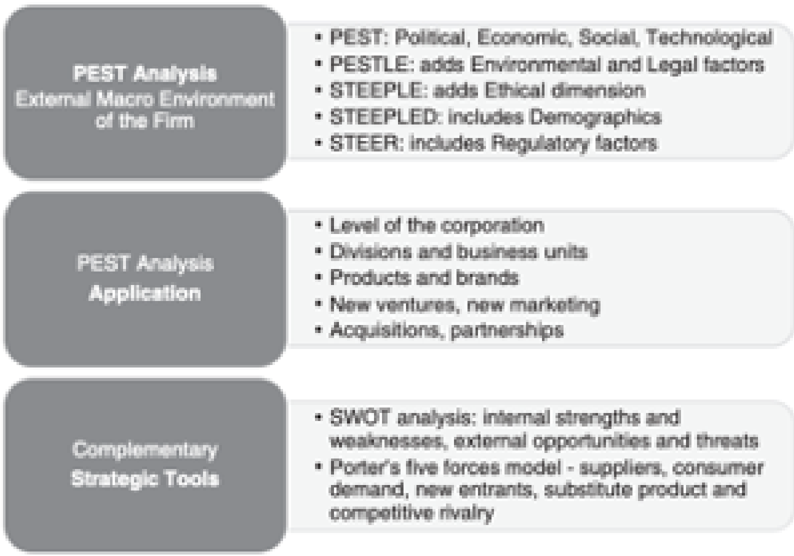

Figure 1.6: Summary of PESTLE (as part of PEST) components, application, and complementary strategic tools. The illustration is from (Sammut-Bonnici and Galea, 2014)

fluence such adoption. In parallel, the regulation of technology can be achieved through different modalities, or 'regulators': law, social norms, markets, and architecture. These four modalities (Lessig, 2009) came to light during the debate on the *unregulable* behaviour of cyberspace as part of Lessig's initial arguments on what it meant to regulate (Lessig, 1999). This model indicates the interdependence of the different regulators which ratifies the concept that the law is not the only force in regulating a subject given in any area. This theory applies to cobot adoption as it puts forward the paradigm on how the different modalities must act on the same field and understand how they interact for a cobot regulation to succeed. The findings from RSQ 1 and RSQ 2 can give insights into the social norms, architecture, and markets constraints on cobot adoption whilst the law will need to consider these factors to ensure legal values are enacted. The four modalities set the precedent for regulatory technologies, highlighting "that more than law alone enables legal values, and law alone cannot guarantee them." To answer the question of regulating disruptive technology like Cobots, we must take into accounts the different factors and actors. As shown in Lessig's work and lessons learned from regulating cyberspace, to ensure the survival of Cobots, making it a viable human-centred technology, the elements of human factors and business will need to be married with the law.

1.3.4 *Summary*

The research areas covered in this PhD thesis are human factors, HCI, business, and law. We have highlighted how the different disciplines are interconnected and their contributions to Cobot adoption. We have seen that in the onion model and PESTLE analysis, regulations, social and ethical implications have the power to influence technology adoption whilst the regulations of Cobots will also be influenced by the technical, social, and economic factors. Our intention is not to create a validated framework but to merely illustrate how different research fields overlap with the law being the prime influence, thus, advocating for the multidisciplinary research with a legal emphasis to tackle Cobot adoption which this thesis aims to deliver. By bringing different principles together, we have created the Thesis Framework to capture the essence of multidisciplinary research and justify the fundamental approach of this thesis. Therefore, the interaction between different disciplines is influential on the final recommendation on Cobot adoption. We appreciate that there are other possible overlapped research disciplines and viewpoints, such as politics, Science, Technology and Society (STS), and philosophy that are not presented here but it is beyond the scope of this PhD. The Thesis Framework demonstrates how the different areas interconnect and the logical order of how the PhD research is conducted.

1.4 RESEARCH ENVIRONMENT AND INFLUENCES

1.4.1 *Context: Horizon CDT and Mixed Reality Lab Research Group*

This PhD research is funded by Horizon Centre for Doctoral Training (CDT) under 'My Life in Data' programme. The programme is multidisciplinary in nature with a focus on personal data and data creativity within the digital economy. The training structure is a combination of taught modules (a total of 180 credits), independent research, and 3-month internship. With the taught modules, there is a set of compulsory modules of 140 credits and optional modules of 40 credits. The taught modules are intended to lay the research foundation and allow students to explore their research topic of interests before narrowing down to a research proposal at the end of Year 1. In aligning to the objective of this programme, the PhD topic focuses on Cobot adoption in a digitally driven environment. In supporting research on this topic, Cognitive Ergonomics in Design and Human-Computer Systems modules are chosen as for the optional modules. Subsequently, Nvivo training and Qualitative training were completed in preparation for conducting and analysing the empirical study. The CDT ensures that the student have the right support in progressing in their study including hosting various activities in nurturing creative writing and camaraderie across all cohorts.

This PhD sits within the Mixed Reality Lab (MRL) research group in Computer Science department. The lab produces a wide range of research and has connections with various research groups. Through the lab resources and network, we were able to recruit key food manufacturers in East Midlands for the empirical study. Moreover, this connection provided a further opportunity to visit the factory to gain real world experience to understand the manufacturing process, the potential integration of Cobots, and the limitation of such adoption in sector specific context.

1.4.2 *Context: Industry Partner and Internship*

At the start of this Chapter, we have previously set the scene by situating Cobots in Industry 4.0, this big picture is influenced by the Industry Partner, DigiTOP.[10] DigiTOP is a collaborative EPSRC funded project between the University of Nottingham, Cranfield University, Loughborough University, and the Bristol Robotics Lab. The project is at the forefront of research in the digital transformation of manufacturing as part of Industry 4.0. The particular concern of DigiTOP is to understand the impacts of digital manufacturing and identify the steps required to support firms into this transition. The project overall objective is to develop an open-access suite of digital tools that provide solutions to overcome organizational, technical, and legal constraints in order to optimize productivity and enhance communication between human workers and robots in manufacturing.

In collaboration with DigiTOP, this PhD research examines the practical and legal consequences of the digital manufacturing technologies with a particular interest in the role of law in the adoption of industrial collaborative embodied autonomous systems. With the support of this project, we have access to a range of expertise, research groups, and private companies that specialise in emerging technologies from IoT to advanced robotics to simulation and modelling (digital twin). We also have a privilege to work with many wonderful researchers in which contributes to a crucial part of the PhD particularly in obtaining resources and leveraging different materials produced by the project to support the PhD's objective. Specifically, this help ensures a rigorous approach to empirical study with access to the project's survey data to back up the expert interview findings. The data collection on DMT helps navigate Cobots research and how they will fit in a bigger picture of digital manufacturing sector. Furthermore, as part of the project's agenda in working in partnership with the industry, we were exposed to practical discussions and real

10 See programme website at https://digitop.ac.uk/

use cases of DMT including factory visits with detailed walkthrough of the production line, the opportunity for improvements with digital technology, and the limitation of machines.

Consequently, through DigiTOP contacts, the mandatory internship was fulfilled as a six-month part-time placement with Made Smarter Innovation (MSI) Challenge, Innovate UK.[11] The MSI Challenge manages over £140 millions of investment, matched by a minimum of £147 millions from industry, to transform the UK's manufacturing capabilities through the development and adoption of industrial digital technologies. The team supports manufacturers and technology developers through various programs such as technology accelerator, research centres, collaborative research and development projects, and innovation hubs. This placement provided full access to all the MSI programs and activities, leading to connection and network with different stakeholders and industry. We're able to gain insights into the public body's funding process and strategy to drive innovation and technology adoption in manufacturing sector which is highly valuable and relevant to the PhD research.

The connection with the industry partner and the internship experience are instrumental in grounding the PhD research in real world applications and keeping up to date with emerging technologies. Accordingly, apart from the theoretical discussions, the viewpoints presented in this PhD research are contribute to the reflection on manufacturing industry insights and experience obtained throughout the period of research.

11 See programme website at https://www.ukri.org/what-we-offer/browse-our-areas-of-investment-and-support/made-smarter-innovation/

1.5 CONTRIBUTIONS

1.5.1 *Context: Academic*

Domestic and healthcare robots are widely discussed with ethical, legal and social implications commonly explored. However, there is a narrow pool of literature in understanding Cobot adoption from the legal perspective; this may present to be a limitation of research topic, but it is equally an opportunity for a contribution in bridging this research gap. To paint a picture, the emerging collaborative industrial embodied autonomous systems explored in this thesis is frequently being referred to as robotics 'co-workers' in a popular culture. This notion is particularly important because it establishes a potential position where this technology might find itself in the future of industrial workplace – being considered as another worker and the concerns from general public/gaining attraction from different stakeholders. This is alarming in many ways for various reasons leading to unwanted consequences such as public fears and backlash as seen with other robot adoptions (Marcu et al., 2023). Cobots are transforming the way of work and certainly how we interact with technology as often that Cobots are being referred to as the 'new coworkers.' This transition will not only challenge the regulatory systems but also our social context. Through this research, we have demonstrated the need for multi-stakeholders engagement in policy making to strike the balance between innovation stimulation and protection of citizens. We synthesized different ideas and insights from industry experts and literature with a diverse range of research fields – cutting across technical, and legal knowledge frames and concepts.

As Cobots are still at the nascent stage; therefore, it is still an emerging field of research. This research is novel in consideration to the nature of the topic, the limited literature in this space, and the key findings. This research also contributes to the interdisciplinary approach of technology law particularly Lessig's 4 modalities framework, proving that the law can regulate emerging technology only to certain extent, thus, the need for collaborative efforts from wider stakeholders, especially, industry. In this case, we applied Lessig's model in a new use case, as well adding more layers in demonstrating the interdependence nature of different 'regulators.'

Therefore, this multidisciplinary PhD provides conceptual and empirical research from different domains to unpack the challenges and implications of collaborative industry embodied autonomous systems in the context of digital manufacturing. In doing this, the PhD seeks to bridge the gap in regulation and literature from different perspectives to what extend the policy needs to be shaped. We also construct the Thesis framework which demonstrates the interconnection of the three disciplines ground the research in a multidisciplinary approach. This framework promotes a process map of developing a sustainable technology adoption ecosystem consisting of 'human factors (design), business, and law. Thus, in this PhD thesis, we managed a complex topic across multiple disciplines.

1.5.2 *Context: Industry*

From policy perspective, following Collingridge's dilemma, one of the ways to regulate innovation is to consider the potential impacts of the technology, however, it is not possible to precisely predict all the potential impacts. The dilemma is whether overregulating might stifle innovation or leaving the innovation unregulated could result in harm. Therefore, this PhD research sets a starting point in exploring the topic and addressing this dilemma by applying a multidisciplinary approach in understanding the challenges through the lens of different stakeholders.

From industry perspective, the regulatory aspect is not always the leading discussion in technology development and discussion. Although it is recognised to be pressing in aligning policies, however, the legal implications of industrial innovation are not yet fully grasped – confirming the valuable contribution of this research.

In summary this PhD thesis contributes to the Industry as the followings:

- This PhD research topic is aligned with the UK government initiatives for wider policy impact on Industry 4.0 by developing insights of Cobot adoption whilst addressing and anticipating the conflicts or tradeoffs or counter-narratives between different stakeholder viewpoints, values, goals and incentives in the technology adoption.
- The thesis findings provide recommendations to help inform the new risks for manufacturers and policy makers for Cobot adoption as well as inform designers of Human-Robot Interaction (HRI) design ethics to support Cobot adoption.
- This PhD thesis is a call to action for all stakeholders to work in collaboration in getting ready for Cobot adoption.

1.6 STRUCTURE OF THE THESIS

The thesis is organised as listed below in Table 1.1 in respective to the research questions in Section 1.2.1.

- RQ: to what extent can the law address the adoption challenges raised by collaborative industrial embodied autonomous systems (Cobots)?
- RSQ1. What are Cobots in the context of Industry 4.0 and the current regulatory landscape??
- RSQ2. What are the legal, ethical, social and organisational challenges and implications of Cobot adoption in digital manufacturing?
- RSQ3. How can the law respond to the challenges found from RSQ2?

A brief summary of each chapter is included in the *Summary* column.

NO.	SUMMARY
Responding to RSQ1	
Chapter 2	Cobots is a fast-moving space, the definition is continuously to change. Recognising that cobots as an evolving term, we first address the state of the art of cobots and justification on the descriptive term of industrial embodied autonomous systems to describe the exact technology space being explored in thesis. We then explore the challenges of cobot adoption and investigate the current cobot regulations. This chapter identifies the landscape of cobots adoption as part of Industry 4.0 movement and establish the scope of cobots by forming a working definition that is a subject matter explored in this thesis. It explores the implications and challenges of cobots adoption discussed in literature based on the definition established in this Chapter.
Responding to RSQ2	

Chapter 3 Chapter 2 demonstrates that there is a gap in literature on the challenges and implications of Cobot adoption. In particularly, although this thesis focuses on a wider definition of Cobots, it is still a niche type of robots that is neither yet widely adopted by the industry nor that they are used as intended. Therefore, this chapter presents an empirical study to identify the legal, ethical and social Cobot adoption challenges identified by industry experts. We conduct a series of semi-structured interviews with industry experts who are in the role of decision makers to understand the challenges and their concerns on the implications of cobots adoption. We identify 10 key challenges and implications of Cobot adoption.

Responding to RSQ3

Chapter 4 In this chapter we examine the role of law in addressing Cobot adoption challenges identified in the Chapter 3. This chapter presents the current regulatory landscape surrounding Cobots by providing the overview on the development of robot law and its lessons learned for Cobot regulation as well as the discussions on liability and safety challenges posed by embodied autonomous systems where data plays a pivotal role. Consequently, we draw close attention to the implications of data in Cobot adoption, in particular, from the perspective of data protection law. This chapter provides insights into the current perceived regulatory gap and the approaches to Cobot regulation in order to facilitate responsible adoption of Cobots in manufacturing.

Responding to RQ

Chapter 5	The chapter reintroduces the research questions and the approaches in addressing Cobot adoption challenges in manufacturing. We reflect on the findings from Chapter 2, Chapter 3 and Chapter 4 in Cobot adoption where we conclude on the scope of law in addressing technology adoption challenges and providing recommendations towards responsible Cobot adoption. We address the thesis limitations, research gaps and future works. This final chapter accentuates the key contributions and the novelty achievement of this PhD thesis in bringing different perspectives together from human-computer interaction to human factors to business to law to explore a complex topic of Cobot adoption challenges.

Table 1.1: Structure of Thesis

2

COBOTS IN DIGITAL MANUFACTURING AS PART OF INDUSTRY 4.0

What is a cobot and its adoption challenges?

Contents

2.1 CHAPTER OVERVIEW

Establishing what is a cobot is the first building block in investigating challenges of collaborative industrial embodied autonomous systems (hereinafter referred to as 'Cobots') adoption in digital manufacturing in which will be explored throughout this thesis. Therefore, the purpose of this chapter is to provide the baseline of Cobots explored within this thesis and the adoption challenges of such technology. As this technology is within an umbrella term of robots, we begin with the general overview of robots and how they are integrated into our everyday life from home to work. Notably, the robot of interest in this thesis is robot at work. We provide examples of robots to demonstrate the different shapes and purposes on this technology, acknowledging that each type of robot is designed based on the required functionalities and purposes from the material to their level of computational capability i.e., 'smartness' or 'autonomy.' To support this, we selected a wide range of robots in different domains, leading to robots at work or robots designed for industrial operation purposes.

To set the scene for Cobots, the nuances of this technology to industrial robots need to be made clear. A Cobot introduces human-robot interactions in the context of industrial applications which is not the same condition as traditional industrial robots. Industrial robots are typically segregated from humans due to health and safety reasons. Therefore, it is necessary to discuss the contentious definition of the term 'cobot' in order to form a clear picture of the technology being explored in this thesis. Furthermore, we unpacked these differences between traditional industrial robots and Cobots and the reasonings for the new term collaborative industrial embodied autonomous systems (Cobots) used in this thesis which is derived from collaborative robotics. In this Chapter, different fields of study and the literature from Human Factors, Human-Computer Interaction (HCI), Human-Robot Interaction (HRI), Engineering, and Computer-Supported Co-operative Work (CSCW) are explored.

Following the definition discussion, we explored Cobot adoption challenges from technological feasibility to legal challenges. This thesis investigates the role of law in addressing adoption challenges, therefore, the overview of the current adoption non-adoption landscape is necessary. The definition of Cobots allow for the broader analysis of adoption challenges described in literature. Consequently, it is reasonable to consider literature which investigate the challenges and impact of other digital manufacturing technology as they also share similar characteristics to Cobots and therefore the challenges are likely to be reflected in Cobot adoption. In this Chapter, the adoption challenges cover from the socio-economical debate on the impact and challenges of technology adoption in manufacturing sectors to the architectural perspectives on safety of Cobots to the liability discussion to trust and acceptance of Cobot adoption to privacy and cybersecurity concerns. These challenges are the reoccurring themes we observe across the literature and conversations by the industry which are discussed in Chapter Empirical Study. This Chapter concludes with the remark that the challenges found in literature are limited and the further implications of Cobot adoption is required in order to identify the potential pain points of Cobot adoption and to what extend can the role of law address such challenges.

2.2 WHAT ARE ROBOTS?

In recent years, the terms 'robot(s)' and 'bot(s)' are used widely for many types of applications from a chatbot, which is a virtual robot, to delivery robots, such as a six-wheel autonomous trolley (Figure 2.1)[1] or a bipedal robot (Figure 2.2)[2]. Robots have begun to take new roles as well. For example, robots have been used as a surgeon's assistant, an elder's therapeutic companion (Figure 2.3)[3] (Figure 2.4) [4], a house

1 This image is from https://www.therobotreport.com/starship-expands-delivery-service-in-the-uk/

2 The image is from https://techcrunch.com/2019/05/21/in-fords-future-two-legged-robots-and-self-driving-cars-could-team-up-on-deliveries/

3 The image is from https://robots.ieee.org/robots/paro/?gallery=photo3

4 The image is from robothttps://www.roboticsbusinessreview.com/health-medical/elliq-social-companion-robot-aimed-at-elders-now-available-for-preorder/

Figure 2.1: Starship

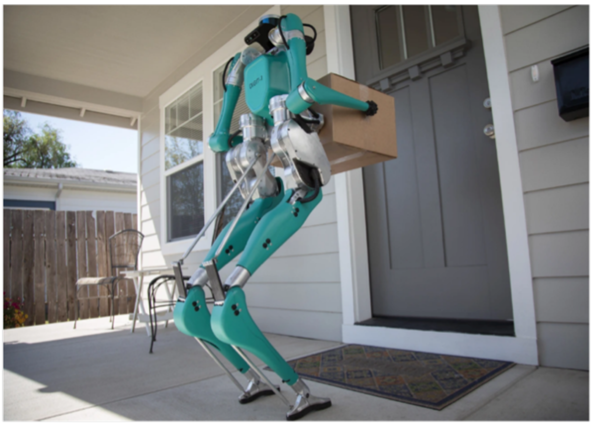

Figure 2.2: Bipedal robot

pet (Figure 2.5)[5], or even a playmate for children (Figure 2.6)[6]. Certain tasks that were traditionally performed by humans can now be supported by robots or bots such as driving or responding to legal enquires. Robots are therefore becoming more integrated in different parts of our lives.

Whilst in some areas robot adoption has a clear benefit and perceived impacts are low, some sectors are facing more resistance than others. In the former sectors, robots are viewed as an opportunity whereas in the latter robots are viewed as a threat. For example, in the retirement communities, the adoption of robot companions by

5 The image is from https://www.theguardian.com/technology/2017/nov/01/sony-aibo-ai-robotic-dog-back-from-dead

6 The image is from https://www.wired.com/story/moxie-is-the-robot-pal-you-dreamed-of-as-a-kid/

Figure 2.3: PARO Therapeutic Robot

Figure 2.4: ElliQ Social Companion Robot

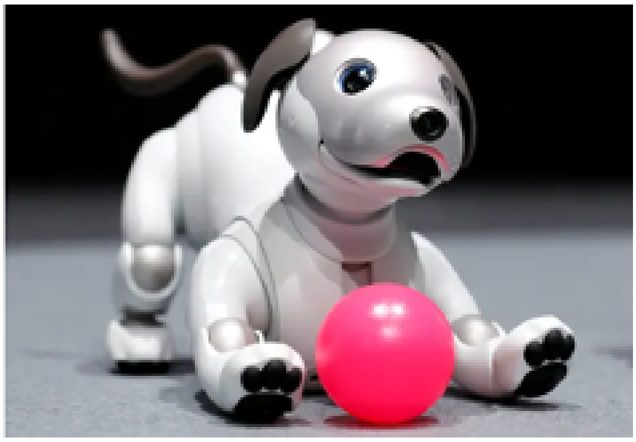

Figure 2.5: Sony Aibo Robot Dog

Figure 2.6: Moxie Social Robot

the elderly is an opportunity to help combat the growing problem of loneliness and generally promote overall good health and well-being. The New York State Office for the Aging (NYSOFA) organized a scheme to distribute robot companion ElliQ to home of older adults to help address the growing problem of social isolation among the elderly. The initial scheme will be tested by 800 adults to help engage in small talk, contact loved ones, and keep track of health goals like exercise and medication (Vincent, 2022). Domestic robots are not viewed as threatening providing that the vision of this type of robot is to increase convenience, comfort, and companionship for users (Urquhart et al., 2019). In contrast, the manufacturing sector faces a heavy backlash on automation and robotics adoption. There are various contributing factors to the resistance, particularly the impact on the workforce caused by machine taking over tasks previously performed by humans. For example, Ed Beecher's essay published in 1962 demonstrates that the concerns about automation are long standing issues even before the arrival of collaborative robotics (Beecher, 1962). Furthermore, industrial robots are frequently subject to greater scrutiny regarding safety concerns, given that fatalities and injuries attributed to robots are often viewed differently than other types of incidents (Oravec, 2021). Accidents involving robots are regularly reported in the mass media painting a gruesome picture that may further contribute to anti-robot sentiments (Associated Press in

Berlin, 2015; Clarke-Billings, 2017). Against this background, robots appear to be positioned as threats to the future of workforce.

Building on this objective, we explore the introduction of human-robot collaboration in digital manufacturing as part of industry revolutions to address some of the above concerns. Previous industrial revolutions paved the way to where manufacturing is today, and the future of it. With the advancement in technology, we start to move forward from the revolution being merely about machines and productivity to understanding the impact on the workforce and focus on the human aspects for better and safer human-machine interaction. Previously, technology was designed to perform tasks with the expectation that the workforce will be designed around it, but recently it has become apparent that humans must (and will) remain the heart of the operations (Leesakul et al., 2022). We accept that this is our appraisal and it may not be the case for all technologies, but the hope for collaborative robotics is that it is not a threat but rather an opportunity.

In this Chapter, we present the research on collaborative industrial embodied autonomous systems (hereinafter referred to as 'Cobots') in manufacturing. Consequently, drawing on the robot law approach, we find that robot regulations which will be further discussed in Chapter 4 are built on previous technological advancement/applications such as Internet of Things (IoT). In this regards, other Digital Manufacturing Technologies (DMT) are also highlighted in this Chapter. DMT share common characteristics with Cobots from the use of sensors to computing process to having a form of collaboration with humans. Furthermore, to better understand different forms of collaboration, we explore the essence of this term further in 3.3.1 through the lens of 'Collaborative Information Seeking' model (Collaborative Information Seeking (CIS)) as part of computer-supported cooperative work (CSCW) field of research [7]. Providing that Cobots have certain elements that can be viewed as a computer system supporting a human operator, this model becomes the baseline in which indicate the levels Cobots engage and collaborate with the humans. The intention is to demonstrate the 'common' misunderstanding of the collaborative nature of Cobots. We find that in human-robot collaboration, the term "collaboration" comes in many tiers. On this basis, we identify and provide a working definition of the robots under discussion. It should be emphasized that the definitions of robots are often dictated by the scholars' background and expertise, we work to provide the most specific working definition and a new term which provides a circumference of the type of robots, the subject matter, examined in the thesis.

2.3 UNDERSTANDING COBOTS IN DIGITAL MANUFACTURING

Before diving into a discussion of Cobot definition in Section 2.3.1, a context of how this technology is introduced into digital manufacturing which arises as part of Industry 4.0 must be provided. In this section, Cobots will not be discussed in depth; the purpose of this section is to provide a background of Cobots as part of a suite of digital manufacturing technologies. These technologies will also be examined as part of Chapter 3 as they share similar characteristics in which support the specific research on Cobots.

The fourth industrial revolution introduces the integration of digital technologies into the manufacturing process to increase productivity and efficiency, leading to the term 'Digital Manufacturing'. Consequently, digital manufacturing technologies (DMT) refer to technologies used in manufacturing that have one or more of the following characteristics: digital, autonomous, and/or intelligent. Such

7 L. J. Bannon and K. Schmidt (1989, p. 359) described it as "a field which covers anything to do with computer support for activities in which more than one person is involved" (also see (K. Schmidt and L. Bannon, 1992; Ludwig et al., 2023)

technologies include sensor technologies, virtual and augmented reality, distributed networking technologies, Artificial Intelligence (AI) [8] and analytics, simulation, and cloud computing (Kang et al., 2016; Oesterreich and Teuteberg, 2016; Chryssolouris et al., 2009; Alcácer and Cruz-Machado, 2019). Industry 4.0 is also known as the introduction of cyber-physical systems in smart factories (Thoben et al., 2017), smart machines are digitally connected with one another – sharing data and making autonomous decisions. The fourth industrial revolution is expected to enable organizations to strengthen their competitive advantage by fundamentally reconfiguring their business operations in order to improve productivity, reduce risks, and increase product quality (Moktadir et al., 2018). Furthermore, this new wave of industrialization is expected to enrich the quality of work by creating a more interesting working environment and greater autonomy for self-development because employees are expected to act as strategic decision-makers and flexible problem-solver (Gorecky et al., 2014; Kaasinen et al., 2020).

2.3.1 *Cobot Definitions: From cobots to Collaborative Industrial Embodied Autonomous Systems (Cobots)*

What really is a cobot? The likelihood of this term being defined in a similar manner by different professionals is low. When this thesis began in 2018, we explored and found many interpretations of a cobot including a criticism towards this term being only a marketing term or simply a redress of a modern industrial robotics. We have then learned that the definition of cobot depends predominantly on what people thought 'cobots' stand for (this is further highlighted in

8 It is to be recognised that the term 'AI' is constantly evolving and there is not universally accepted definition. In broad term, AI is "the study of the computations that make it possible to perceive, reason, and act" (Winston, 1992). In this thesis, we adopted the definition outlined by the ICO "AI is an umbrella term for a range of technologies and approaches that often attempt to mimic human thought to solve complex tasks." (Information Commissioner's Office (ICO), n.d.).

3.3.1). For instance, in 2021 the Cobot Maker Space was formed at the University of Nottingham to promote the research and design of human robot interaction. The Space cites a cobot as a robot to "support people with tasks that are uncomfortable, repetitive or even impossible, such as holding and moving heavy materials or surveying inaccessible areas. Effectively, cobots can bridge gaps in our senses, augment our own capabilities and compliment them." Despite what the name of the lab suggested, the term 'cobot' does not appear to be prescriptively defined.

As mentioned above, a cobot is a portmanteau word for collaborative robotics in manufacturing. At the start of this thesis research, most of the literature on cobots was from the field of engineering and cobots being the only type of industrial robots that, by definition, was designed to operate without a physical barrier, allowing for human workers to be close to it (Michaelis et al., 2020). This description does not suggest any form of collaboration but merely robot co-existing in the same environment as the humans. Similarly, from an industry perspective, an industry publication, the Manufacturer, cited collaborative robots as "lightweight and compact, they can work right alongside humans thanks to soft skin and force-limiting sensors that keep the energy of any collision at a safe level." Unlike what the Cobot Maker Space suggested, this definition does not mention cobot as a medium that allows for human robot interaction but it gives characteristics of a cobot that is safe to operate around humans based on its mechanics and exterior design. Adding to the lack of unanimous definition, collaborative robotics to a layman can be perceived as a self-explanatory term meaning a robot that can collaborate with a human as opposed to a type of industrial robots. In this definition, the term itself is rather a straightforward term that suggested exactly what its purpose is in a similar manner to footpath, sidewalk, carpark, sunglasses etc. In a paper by Studley and Winfield (2020), they said that "many projects foresee robots in industry as co-workers (or 'cobots')" (Winfield et al., 2021). Studley and Winfield are professors of robot and technology ethics, as experts, they also viewed research on 'cobots' differently. The selected word of 'foresee' signifies their need to highlight the view of what the future of industrial robots could become, a robot co-worker[9], as opposed to what the term cobot is being used for the current time. Meanwhile, the European Commission has a different interpretation of collaborative robotics and views it as an umbrella term for advanced technologies. In the Proposal for a Regulation of the European Parliament and of the Council on machinery products (2021) (EU, 2021), cobots are described as:

> *"Recently, more advanced machines, which are less dependent on human operators, have been introduced on the market. These machines, known as collaborative robots or cobots, are working on defined tasks and in structured environments, yet they can learn to perform new actions in this context and become more autonomous." - Recital 11*[10]

Following the European Commission's definition, it can be summarized that at present cobots are used to refer to all current embodied Artificial Intelligence. Interestingly, ISO actually refers to cobots as a robot system that share workspace with human workers but not necessary collaborating with them. The definition provided in Technical Specification of ISO 15066 (Robotics, 2016) is:

> *"Any collaborative robot system design requires protective measures to ensure the operator's safety at all times during collaborative robot operation. A risk assessment is necessary to identify the hazards and estimate the risks associated with a collaborative*

9 Also see You and Robert Jr., 2018 for further exploration on this concept

10 Interestingly, the term 'cobots' is not used in the final draft of the Regulation and they rather fall within the umbrella term of 'advanced machinery' *"such machinery is working on defined tasks and in structured environments, yet it can learn to perform new actions in this context and become more autonomous. Further refinements to machinery, already in place or to be expected, include real-time processing of information, problem solving, mobility, sensor systems, learning, adaptability, and capability of operating in unstructured environments"* - Recital 12 (Regulation (EU), 2023/1230)

robot system application so that proper risk reduction measures can be selected."

Whereas collaborative operation is

"a state in which a purposely designed robot system and an operator work within a collaborative workspace."

And collaborative workspace is

"space within the operating space where the robot system (including the workplace) and a human can perform tasks concurrently during production operation."

Based on this definition, although the term collaborative robotics may suggest that a robot is able to collaborate with an operator, collaborative robots are not necessarily designed to work with operators in the same way that human operators would collaborate with each other to accomplish a task. This description adds to the complexity in identifying collaborative robotics. In attempting to conceptualise the term, we believe it is crucial to start from the technical definition of 'collaboration.' As the collaborative robot suggests the element of collaborations, we need to understand what does the term entail. In this regard, the concept of 'Collaborative Information Seeking' (hereinafter as CIS) can help unpacking this definition. CIS suggests the different levels of collaboration which can be applied to the context of collaborative activities between human and robot. In accordance to Shah (2014), a model of collaboration consists of 5 layers with collaboration encapsulating the others (see **??** [11] (El Zaatari et al., 2019). This

11 The illustration is from Shah, 2010).

This model identifies the different levels and steps of towards true collaborations ranging from communication, contribution, coordination, and cooperation. In applying this to the term collaborative robotics, it can be viewed that to be considered as collaborative robots, the robot needs to, at the very least, communicate and exchange information with human workers. For example, this could simply be the ability to react to verbal instructions from the human workers and perform tasks accordingly. Contribution refers to how the robot can help human workers in achieving their in-signifies that the term collaborative robotics is referred to only specific types of industrial robots for Human-Robot Collaboration (HRC) but the term itself seems to only limited to one type of robot and does not capture all of robots for human-robot collaboration. When tracing back to the starting point of the term cobot, the misalignment in timeline potentially substantiates that the meaning of the term has

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dividual goals. For example, a robot is able to deliver a required tool to the relevant human workers in order to help them perform their tasks. For coordination, this involves a robot being able to work within an environment where it needs to connect the information from different sources and interact with other robots. For example, a robot will need to know how to plan a route to manoeuvre around the factory floor without running into other robot trolleys or humans to deliver the material to the production line. In the case of cooperation, there will be a clear role in which a robot and a human worker will need to perform together in a sequence for a joint goal. For example, at an assembling station, a robot will hold up a door in place while a human worker drills the door into a body of a car.

Lastly, in achieving the collaboration level, a robot will need to be able to understand how to support the human workers without being verbally instructed and to creatively approach to perform the tasks. This level of collaboration will likely involve the ability to understand and anticipate behaviours of the human workers such as knowing when to hand over out a tool required to perform a task before the human reaches that stage. All in all, this model demonstrates the range and levels of collaborations which we can potentially expect from a collaborative robot to be able to perform, highlighting the wider scope of what human-robot collaboration entails and the types of robots that should fall within scope of the term cobot.

These few examples are chosen to illustrate a spectrum of meanings attributed to cobots: the past, the present, and the future. Collaborative robotics may very well be what a cobot stands for, however, the reality is this technology will continue to change. As this thesis advances, we acknowledge this discrepancy in cobot definition especially the shortcoming of how collaborative robotics is often only used to refer to smart robotics arms in manufacturing (Javaid et al., 2022). As human-robot collaboration is not limited to only one type of industrial robotics, this distinction needs to be made clear particularly in how the term cobot is used in this thesis. From a legal perspective, a definition of a term is highly important. A description of the technology has to be precise though this rigidness is often proven as a flaw in the legal system in coping with the fluidity of the technology advancement which will be discussed further in Chapter 4. This Section investigates the cobots definition, the current state of the art of what perceived as cobots in accordance with this thesis working definition, and the future of cobots.

changed over time and explains why there is not a universal definition for cobots. In order to keep up with the development of cobots, the working definition of cobots in this PhD thesis will need to be non-restrictive. We first defined cobots as robots with some or all of these general attributes: ability to assist humans in a large diversity of tasks; understand its collaborator's intentions and communicating its own; predict human actions and adapting to human behaviour; decide when to lead the task or when to follow the user by rapidly adapting to the user's actions or requirements. However, this definition was quite difficult to work with, thus, it raised the need to form a better working definition – a simplified version of all the mentioned attributes.

As we moved forward to simplify the definition, we have found a contradiction point in the literature where collaborative robotics are interchangeably referred to as an emerging robotics system or an application of where the industrial robot is safe to operate side-by-side human workers or a new type of industrial robot. The question lies of whether it is the software or the hardware, or both, that make a robot a cobot? It appears that the common denominator of whether cobots are a new emerging type of robot or merely a robotics system or application of robot is that a robot must be safe to operate in the same space or collaborate with human workers as well as having some levels of autonomy. In terms of to what degree cobots are meant

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2.3.2 *Cobots Described in Literature*

With collaborative robotics (hereinafter referred to as 'cobots'), we are transitioning away from human-operated robot and enter the world of human-robot interaction, from robot operation fully controlled by humans to a situation where robots share a task with humans and they both have autonomy over their actions. Schou et al. (2018) identified that a term 'cobot' was first introduced in 1996 as "mechanical devices used to aid humans in solving industrial tasks" while Jocelyn and others claimed that cobots began to be introduced into industrial environments around 2010. Consequently, according to Zaatari and others, "cobots have been increasingly adopted in industries to facilitate human–robot collaboration" to interact with human workers, that will depend on the nature of the task.

Consequently, when examining the task and the levels of autonomy, we find cobots to be classified into 3 different applications or types: robot assistants, truly collaborative robots, and managerial robots. Robot assistants are designed to assist or operate alongside human operators, whereas truly collaborative robots are meant to directly collaborate with the human worker to solve industrial tasks as a team. Managerial robots merge together the robot assistant and truly collaborative robots. Researchers are looking into designing this type of Cobot to "keep a record of project progress, provide real-time scheduling and decision support, and hold perfect recall (and remind others) of complex policies and procedures, while communicating with people in a natural, social way" (Davenport and Kirby, 2014).

In terms of robotic system architecture, the two main approaches for robot programming systems are manual programming and automatic programming (Biggs and MacDonald, 2003). The latter allows the robot to be less dependent on detailed instruction as autonomous systems are able to create algorithms based on sensor inputs and a comprehensive world model; for example, the sense-plan-act (SPA) architecture is one of the classic approaches where robots learn to switch between sensing, planning, and acting states (Schou et al., 2018). To train Cobots, programming by demonstration is deployed. This approach aims to teach a robot of its task in human–robot collaboration scenarios so that it can communicate with the operator, understand their needs, and behave accordingly (Rozo et al., 2016). Overall, with high expectations for Cobots, their ability to learn is crucial. Some of the modern research focuses on the ability for robots to gather knowledge, formalize it, and share that information (Suh et al., 2007; Lemaignan et al., 2010).

It is necessary to understand the different levels of collaboration as it will have different implications and challenges in legal research context. By applying this model, it can be implied that Cobots are designed to be safe to operate around a human operator while at the lowest level the robot has to be able to communicate with the operator (i.e. robot relies on understanding the environment and the operator's action so it does not get in their way) and at the high level of being able to contribute, coordinate, and cooperate with a human operator to achieve a shared goal and/or task.

Overall, the benefit of implementing Cobots into the workplace allows to maximize efficiency at work. With human-robot collaboration, the advantages are the combination of high levels of accuracy, strength, precision, speed, endurance and repeatability from the robot and the flexibility, sensitivity, creativity and cognitive skills from the human. Nonetheless, this notion requires further investigation. Cobots have a great potential to become more integrated into the shop floor in the upcoming future but the increasing level of their automated behavior can pose various risks to human workers and the organizations.

We conclude that what makes a robot a Cobot is based on their functions and how they engage with humans. Prescribing a fixed definition of what a Cobot is will only limit what the technology can become. Therefore, in this thesis, we are interested in Cobots that enable human-robot collaboration and where collaboration comes at different tiers as illustrated in **??** discussed above.

2.3.2.1 *Cobot State of the Art*

As discussed in Section 2.1, Cobots are not limited to industrial collaborative robotics, therefore, they come in many shapes and forms and can be used for different purposes. When exploring the commercial state of the art of Cobots as described in the thesis, we focus on the robots as embodied autonomous systems in which are designed to be safely operating in the same environment or with human workers. In the commercial space, we looked for Cobots that are specifically advertised for manufacturing and those not advertised for manufacturing but with the potential to be used in the factory. The term 'cobots' advertised for manufacturing sector often promote as robotics arm solutions as "easy to program, fast to set up, flexible and mobile, safe" (Marr, 2018). However, they are limited to assembly line work such as lifting and placing items in the assembly. There are various companies that specialized in such type of Cobots. Table 2.1 below presents examples of cobot for different applications from both industry and academic projects. This list is not exhaustive as the purpose of this table is to illustrate the current technology landscape of Cobots.

TYPE	APPLICATION
Robot Assistants	Osaro, AI software startup, integrated deep reinforcement learning AI software in robot, allowing it "to use visual recognition, speech, and navigation out in the real world" See link here
Robot Assistants	UC Berkeley spinoff covariant.ai (formerly Embodied Intelligence) uses AI and VR to teach robots new skills. See link here
Robot Assistants	Robotics Arm (perception training, visual and haptics): See Universal Robots, See KUKA, See ABB, See Boston Dynamics
Robot Assistants	Robotics Arm (perception training: improved haptics): See MIT soft robot, See Robo-Dumbo (robot elephant trunk, See DEXTERITY
Robot Assistants	Robotics arm (perception training: visual and sound): See CMU's Robotics Institute
Robot Assistants	Autonomous Mobile Robot (AMR): See Arculus, See MiR, See Temi, See OTTO, See Temi, See STARSHIP
Robot Assistants	Bipedal Delivery robot:
Robot Assistants	4 Legged-robot: For industrial work see SPOT, For delivery see ANYmal
Robot Assistants	Autonomous Robot Vacuum See WHIZ

Table 2.1: Commercial state of the art of Cobot

TYPE	APPLICATION
Truly Collaborative Robots	SecondHands – EU Horizon 2020 project, humanoid Cobot aimed to be truly collaborative SEE LINK here

Table 2.1: Commercial state of the art of Cobot

2.3.2.2 *The Adoption of Cobots*

Furthermore, it is important to explore different practical examples that show actual experience and practices with the deployment of a form of Cobots in workplaces including the benefits as well as issues. However, it should be noted that in manufacturing sector, the level of human-robot collaboration in the existing industrial applications of Cobots is quite low even though industry finds Cobot to be useful for new assembly processes, making designing collaborative tasks one of the focus areas in the future of Cobots (Aaltonen and Salmi, 2019). Furthermore, in existing literature, there are more about perspectives but not many on the practical case studies of Cobot adoption. For example, L. Liu et al. (2022) conducted a systematic literature review to provide a better understanding of the development and application of Cobots in manufacturing sector and identify relevant "hot spots and specific contents of the existing Cobot research." Similarly, Kopp et al. (2021) investigated the practitioners' perspective and researchers' point of view on relevant aspects and possible success factors for introducing industrial human-robot interaction in enterprises using a mixed method approach comprising of a systematic literature review and an online survey of 81 company representatives. The authors found that it was difficult to find successful human-robot collaboration in practice especially in SMEs notwithstanding the show cases and pilot implementations. Furthermore, the authors cited that most research focuses on social or humanoid robots within a service context in exploring technical challenges of HRI.

Therefore, since the currently deployed Cobots may not be truly collaborative robots, there are limited case studies available which present a challenge in finding practical examples of Cobot adoption. However, there are examples of a form of Cobots (with low to no levels of HRC) that can help demonstrate potential challenges and provide insights into what adoption might involve when Cobots advance and gain wider acceptance. For instance, Schumacher et al. (2022) presented a case study of collaborative robots in welding (a manufacturing process to join materials) in SMEs in Germany. It should be noted that in this study, a standard collaborative robotic arm was explored for welding in the context of a collaborative operation.[12] However, the authors did not specifically address the context of humans and robots working together on collaborative tasks, which is the focus of Cobots explored in this thesis. Nonetheless, the authors cited the benefits of this type of collaborative robots in welding including, but not limited to, decreased exposure to toxic fumes for welders, reduced eye strain, and lowered physical strain related to uncomfortable postures. The study also highlighted technology adoption barriers, such as, management and workers reluctance to embrace new technology, humans' superior ability to adjust to unexpected events and handle complex or critical tasks, and dthe potential for cobots to leave behind mundane and monotonous tasks due to partial automation.

Moreover, despite the difficulty in finding practical examples where Cobots are used in a manner described in the thesis (i.e., as robotics 'coworkers'), we recognise that there are lessons to be learned from practical examples regarding actual practices and issues of 'robots at

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12 Schumacher et al. (2022) discussed that a collaborative operation is defined in four different interaction levels "(1) shared workspace without shared task; (2) shared workspace and shared task without physical interaction; (3) Shared workspace and shared task that is "handed-over" from human to robot; and (4) shared workspace and shared task with physical interaction.

work' that extend beyond the manufacturing sector. Ljungblad et al. (2012) presented a case study of robots used in a semi-public hospital environment to transport goods and samples for an orthopedic department. In this study, an autonomous robot was deployed for 13 days with a technician following the robot around with a wireless connection to support potential technical challenges. Hospital staff found the robot to be useful; however, there were some concerns, including job displacement and staff reduction, slower and inaccurate navigation for sample delivery resulting in longer waiting times, limitations on the errands the robot could support, and safety concerns regarding its interaction with patients and the possibility of collisions if someone is in the way. Moreover, regarding the interaction and role of robots, the authors found that people's perceptions are divided into four perspectives: as an alien, a machine, a worker, and a colleague. People considered the robot to be an alien as it was perceived to be clumsy, and its movements seemed unfamiliar to people, leading to uncertainty about the robot's purpose and behavior. Some people viewed the robot solely as a machine. Others considered it to fulfill a worker role within the hospital, suggesting that it should be clearly identified as part of the hospital staff or equipment (e.g., showing that it works at the hospital and the department it belongs to) for visitors and patients. Lastly, the robot was described as almost a work partner; when staff first met the robot, they described it as meeting a new colleague. Therefore, this case study demonstrates the potential challenges and acceptance of Cobots, highlighting the importance clarifying the role of the robot and what it is there to do.

There are also more recent development of robots used in hospital from commercial deployment perspective. Moxi is a mobile manipulation service robot claimed by the company that can assist hospital staff in "delivering lab samples that are normally hand-delivered, delivering medicines, fetching items from patient care units," as claimed by the company (Thomaz, 2023; Diligent Robotics, n.d.). However, this one-handed robot, designed for hospitals, is not as versatile and easy to deploy as claimed. Diligent Robotics (n.d.) asserted that the challenge of deploying Moxi may stem from the lack of appropriate infrastructure for such technology, as many hospitals were not designed with rolling robots equipped with pinchers for hands in mind. Additionally, the robot cannot open every type of door or navigate stairs. Therefore, it is important that the design of Cobots takes into consideration the realistic environment where the robots will be deployed and operated, including the manufacturing process and common facilities.

Another use case to consider is Cobots as autonomous mobile robots. Following the Covid-19 pandemic, Starship grocery delivery robots were introduced in Milton Keynes (MK), England, to automate tasks that were deemed unsafe at the time, such as, delivering groceries or visiting the supermarket. Valdez et al. (2021) presented several considerations regarding the introduction of this technology, including the lack of regulations and legal precedent for dealing with unaccompanied autonomous robots in urban environments, as well as concerns about the safety of robotic operation. It was found that the robots performed well in MK due to its low population density and extensive network of segregated paths for pedestrians and cyclists which made it easy for the robots to navigate. However, the authors noted that it might not have the same outcome if the robots were deployed in cities with crowded sidewalks, such as London and New York. In such environments, it would be challenging for robots to understand the flow of pedestrians (i.e., to learn to either 'go with the flow' or 'get out of the way'), potentially causing considerable inconvenience and risk for pedestrians. Similar to the case study of Moxi, understanding how humans operate, including the psychological aspects of human behavior, will be another challenge to consider for Cobot adoption to ensure smooth integration and alignment with the entire manufacturing operation.

These examples suggest that commercially available robots may not be as practical as required by the industry yet. Furthermore, whilst some of these examples may not be from manufacturing, they still provide insights into the potential future of Cobot adoption in the real world, which will be discussed in the next section.

2.3.3 *Future of Cobots*

As demonstrated in the sections above, Cobots as collaborative industrial embodied autonomous systems cover a wide range of robotics technology from an autonomous trolley to half-body robots with facial expressions. The purpose of Cobots also vary depending on the design as well as level of autonomy which we have described previously in 2.3.2 as robot assistants, truly collaborative robots, and managerial robots. Currently, it appears that assistive robots are more commonly discussed in the literature but the sector is moving towards further robotics development where they can actually collaborate with humans in a similar way we interact with each other, such as, understanding body language and being able to anticipate the next action or movement required to collaborate on certain tasks (Tsarouchi et al., 2017). For example, a Cobot will start to learn how to act and performs tasks by observing the human trainers and predicting the next action such as handing over of certain tool that required to perform the task before a verbal instruction is given (Patel et al., 2023; S. Li et al., 2023). With managerial robots, Cobots will likely perform the role in monitoring tasks performed by other robots as well as collaborative tasks between human and robots whilst providing resources in accomplishing such task (Dixon et al., 2021).

Certainly, these scenarios and types of robots are quite speculative. However, to understand the adoption challenges and the role of law in regulating this technology to facilitate the adoption, it is important that we consider the future of Cobots. As discussed by Ballard and Calo in Forecasting as Method in Robotics Law and Policy, future studies research method, commonly known in human-computer interaction (HCI) field, can be highly critical in understand the future of technology and the potential pitfalls as well as unintended consequences (Ballard and Calo, 2019).This research method is to transform ""unknown unknowns" into "known unknowns" to build out a more complete picture of technology's potential trajectory and social impact" (ibid., p.6). In this thesis, it is not within our scope to dive into this research method, however, we recognise the importance of this practice and its contribution in building the basis of the Cobots and its disruptive nature to ways of working in manufacturing sector. We argue that this method can help paint the bigger picture of Cobot adoption and in understand the future of technology acceptance. In considering different scenarios and contexts of use, we can gain more insights of the potential challenges and implications of this technology.

Consequently, the role of robots will start to change over time. As the sector is moving towards Industry 5.0 [13] highlighting the importance of human-robot collaboration, we will start see Cobots taking on new roles in which we did not expect. For example, with the major event of the COVID-19 pandemic where technology like Cobots became essential in mitigating the impacts of pandemic by using this type of robots to do the disinfecting tasks in order to prevent exposure to the virus (Yoganandhan et al., 2021). In this scenario, although we have highlighted before that Cobots would likely to take on more mundane tasks, in this case, a robot was taking a crucial role in maintaining a space to help in preventing further outbreak of the virus, which is a critical task during this period of time. Therefore, it is likely that the perception towards autonomous systems may be viewed differently as the benefits become more apparent, especially during a time in which the tasks are dangerous for humans, but to prevent the economy from collapsing, autonomous systems become the viable option as opposed to a threat to employment. Therefore,

13 According to Kaasinen et al. (2022) Industry 5.0 refers to an industrial transition to "become a resilient provider of prosperity, by having a high degree of robustness, focusing on sustainable production, and placing the wellbeing of industry workers at the center of the production process (p.1)."

in this thesis, we adopt the anticipatory approach in establishing a new term of collaborative industrial embodied autonomous systems (hereinafter referred to as 'Cobot') to capture the wide range of industrial robots that enable human-robot collaborations and the future of such technology which will be used in discussion with experts in Chapter 3.

2.4 COBOT ADOPTION IMPLICATIONS AND CHALLENGES

Following the constant development on robotics and AI liability frameworks, it is evident that emerging technologies are deemed to raise new risks. However, there is a lack of research on the legal, ethical, and social consequences and impact of next generation industrial robotics technologies (Winfield et al., 2021). Therefore, in exploring the adoption challenges of Cobot, it is crucial to understand the legal, social, ethical and organisational impacts of technology adoption. In drawing together knowledge from different disciplines from human factors (Figure 1.5) to business (Figure 1.6) to law, we proposed that the adoption challenges need to be in considerations of these the key factors we have identified in Section 1.3.

As we have discussed thus far in this Chapter, Cobots have the potential to revolutionise the manufacturing process, working alongside humans and support industrial tasks. Despite these promising benefits, there are various constrains, such as, data security issues, financial capability, technology maturity, and knowledge competencies (Ghobakhloo, 2018), that need to be overcome before the transition into Industry 4.0 can be completed. For example, firms will need to consider different strategies to train employees and prepare for the new shift into the workspace with a high level of complexity and the introduction of advanced technology. In addition, the challenge for businesses will be around how to manage human resources and increase worker skill sets to support the change in working environments (Hecklau et al., 2016b). Human workers will also need to adapt and learn to work in conjunction with robots.

Furthermore, one of the prominent social and ethical concerns of more technological integrated workplace is the fear of job loss to automation (Spencer, 2018). Although this concern needs to also viewed under scrutiny as presenting in the counter debate by Professor McAuley referring to "Cobots" as collaborative, cooperative robots "arguing that they will always need to work alongside humans, rather than instead of them" (Blackall, 2021). Therefore, Industry 4.0 is becoming a popular research topic in both academic and business arenas.

At present, the use of Cobots to their full potential in UK manufacturing is restricted by a lack of legislation to support their use. Although robotics in manufacturing is heavily regulated, the current standards are not appropriate to govern the implementation of Cobots. There are strict policies on safety protocols, such as, physical barriers, sensors and other systems to prevent people from being in close proximity to the robot while it is working and to ensure that the robot automatically stops when people are within certain range; however, isolating Cobots in cages will entirely defeat the purpose of this technology. The safety challenges with Cobots cannot be overcome by simply installing standard movement detection; the autonomous aspect of Cobots also requires additional safety standards for decision-making criteria programmed into robots. As Cobots learn from human workers, the system must enable robots to distinguish desirable behaviors from harmful behaviors so that a robot can only replicate the appropriate human gestures (Burke et al., 2006). Consequently, the interactions between Cobots and humans also create the norms of endless personal data collection and processing which can face difficulty with data protection law.

2.4.1 *Socio-economical Debate and Workforce Sustainability*

The transformation of business operations brings forward new challenges including a shift in the workforce from recruiting new talents to modifying daily tasks. The public and academic debates centre around the impact of digital technologies on employment (Brynjolfsson and McAfee, 2014). In particular, the economics debate of technological unemployment is explored by various scholars in the case of quantification of the impact of computerisation on the workplace. A study by Frey and Osborne investigates this 'technological unemployment' whereby they estimated that 47% of all US occupations are susceptible to being replaced by computerization in the next 10 to 20 years (Frey and Osborne, 2017).The Scientific Foresight Unit STOA of the European Parliamentary Research service emphasizes that "it is hard to quantify the effect that robots, AI and sensors will have on the workforce because we are in the early stages of the technology revolution" (Bird et al., 2020, p.634). According to a study by Smith and Anderson economics experts believe that robots and AI would displace both 'blue' and 'white' collar workers, leading to an increased number of unemployed people and vast income inequality (Smith and J. Anderson, 2014). However, Arntz, Gregory, and Zierahn argue that various studies overestimate the share of automatable jobs because they fail to recognize the "substantial heterogeneity of tasks within occupations as well as the adaptability of jobs in the digital transformation" and by applying their method, they found that the automation risk of US jobs dropped to 9% (Arntz et al., 2017, p.157).

Moreover, digital transformation introduces unprecedented levels of skills gaps and shortages where some of the traditional jobs are left unfilled and the new 'digitalisation' jobs require skills that older employees do not have. A report conducted by Deloitte and the Manufacturing Institute forecasted that over the next decade more than 2.6 million baby boomers (those born between 1946 and 1964) in the US are expected to retire despite of delaying retirement, which could lead to a demographic challenge for the manufacturing industry (Giffi et al., 2018). Workers will need higher qualifications and skills as the roles are becoming increasingly more complex with tasks shifting from routine process to controlling the machines in real-time by incorporating analytical information given by new software systems (Matt et al., 2020).

Notwithstanding the economics debate, research shows that human operators will remain vital elements of the manufacturing industry. Technologies will need to be designed to support and work with the workers. Therefore, workforce issues and acceptance of new technologies need to be addressed (De Bernardini, 2016). However, very few Industry 4.0 studies focus on the human resources and organisational impacts, while the majority of the research concentrates on technological or infrastructural aspects (Matt et al., 2020). There is also a lack of research on the legal, ethical, and social consequences and impact of digital manufacturing technologies on the workforce from a human factors viewpoint (Winfield et al., 2021). There are some studies dedicated to understand the barriers to adoption which focus on technology acceptance within SMEs (Winfield et al., 2021; Fletcher et al., 2020; Masood and Sonntag, 2020). Particularly, a study by Kildal and others identify key concerns and attitudes towards collaborative human-robot systems. Their results show that a lack of knowledge is the principal barrier to adoption, followed by workers' acceptance, cost, and regulation. The study was conducted in the form of a workshop with one hundred industry professionals that were already users of Cobots or were considering introducing them in their processes in the future. However, it is unclear whether the study reflects the perspective of different stakeholders.

Interestingly, Lotz et al. (2019) conducted in-depth expert interviews with five industrial employees (three workers and two heads of department) where they found that from the employer's perspective an inherent problem stems from the lack of certainty in regulation. Conversely, employees' main concerns are about their safety to work alongside robots and worries about their job security fearing that robots will take over their positions (Lotz et al., 2019). Another study found workforce skills, resistance to change, and anxiety to be challenges to technology adoption (Vogelsang et al., 2019). Legal obligations and finance appear to be the common concerns from a business viewpoint, although, impacts on employees are equally important. To get a better understanding of these impacts on employees, Tabrizi and others argued in their article 'Digital Transformation is not about Technology' that it is important to leverage insiders to transform organisations because staff have an "intimate knowledge about what works and what does not in their daily operations" (Tabrizi et al., 2019).

Despite the potential of digital technology to improve working conditions and job satisfaction, it can also have aspects that have a negative impact on employees and thereby impede a sustainable workforce. As stated by LeBlanc and Oerlemans highly innovative sectors that have to cope with constant technological changes as well as strong international competition are in need of a sustainable workforce (Le Blanc and Oerlemans, 2016). Initially, a sustainable workforce was conceptualized as employees being able to keep on working while retaining their health and well-being or in terms of adaptability to a multitude of work-related change (Le Blanc and Oerlemans, 2016; Fugate et al., 2004). However, LeBlanc and Oerlemans indicate that being healthy and able to keep on working is not enough; employees have to be pro-active and demonstrate creative and innovative work behaviour (Le Blanc and Oerlemans, 2016). This personal initiative is key to employee sustainability and of vital importance for the viability and competitive advantage of contemporary organisations. Furthermore, other prominent reoccurring themes across literature are *safety*, *liability*, *trust*, and *privacy*. These themes will also be validated against the findings from the exploratory research.

2.4.2 *Safety*

Cobots are meant to have direct contact with humans; thus, guaranteed safety of Cobots must be satisfied at all time (Kildal et al., 2018). Therefore, it is important to consider whether safety standards governing traditional industrial robots are at the adequate level of safety requirements needed for Cobots to ensure the safety of human operators. At the time of writing, legal provision governing the design of robots are the Machinery Directive 2006/42/EC which is implemented in the UK Supply of Machinery (Safety) Regulations 2008 and the Product Liability Directive 85/374/EEC implemented in the Consumer Protection Act 1987 (also see Ponce, 2017). Though, it is worth noting the potential changes of the legal provision considering the post-Brexit position of EU law in the UK. However, at the time of writing, the European Union Act remains in force. However, post-departure CJEU case law may be used as persuasive authority in the interpretation the provisions of the Act that implement the Directive, but will not be binding on the UK courts. Also, product liability and consumer protection laws only apply to domestic Cobots rather than industrial Cobots. Nonetheless, in the UK, Health and Safety at Work etc. Act 1974 and The Management of Health and Safety at Work Regulations 1999 provide general requirements for workplace safety. However, there is not a specific set of rules that clearly define the required safety elements in Cobots that can be legally enforced.

Currently, the only conventional form of regulation with clear guidelines on the safety Cobots design is International Organization for Standardization, which is available as a guideline for Cobots safety measure through its most recent technical specification (TS 15066) (Robotics, 2016). ISO defines four key measures: Safety-rated monitored stop (the work stops when a worker enters the workspace of the robot), Hand guiding (the robot moves only under a human worker's control) Speed and separation monitoring (control the speed when human worker is approaching), Power and force limiting (the amount of force robots could exert) (Vargas, 2018). From a technical perspective, there are various research projects focused on the design and safeguards for the physical safety of Cobots. These projects include, but are not limited to, the materials use for constructing the robot, system and software controlling the robot, all sensors equipped in the robot to prevent harm to a human worker and to the robot itself (Vasic and Billard, 2013; Rosenstrauch and Krüger, 2017). Some of the previous prominent study domains in the area of physical safety of human robot interactions: the human-robot interaction safety assessment and concepts in quantitative terms, the mechanical designs of robotic systems (i.e. variable stiffness in actuators), and planning and control schemes such as collision detecting system to prevent collision and reduce the impact force during collisions (Alami et al., 2006; Kulić and Croft, 2006; Heinzmann and Zelinsky, 2003; H. Liu et al., 2005; Wosch et al., 2002; Follett, 2014; Pervez and Ryu, 2008). The challenges will be translating these actionable technical concepts into the law.

Accordingly, besides physical safety risks with Cobots, mental health risks are needed to be examined providing the cognitive interactions between a robot and a human worker. A study shows with human-robot interaction, the flows of information exchange between a human worker and a robot worker go both ways with an equal level of importance for both workers in regards to work process (Murashov et al., 2016). However, humans cannot process same amount of information as quickly as machines. This notion is also discussed as part of 'Ironies of Automation' (Bainbridge, 1983) (also see in 1.3.1); thus, it raises a question around mental health risks if human-robot interaction will require a human operator to react at the same speed as the robot. This is also held true in the case of human supervising robots. The ratio between the robots and human supervisor can heighten this challenge as the supervisor would experience more workload with the addition of each robot. This is due to a constant need for human supervisor's limited attention resources to switch attention from one robot to another to monitor the robot's actions which may contribute to stress during time critical deployments (Wong and Seet, 2017). The safety governance of Cobots must address both physical and cognitive risks, though the latter has not been mentioned much in robotics safety research.

2.4.3 *Liability*

What distinguishes Cobots from the industrial robots is the ability to adapt and assist humans. Although the application of AI in robotics is becoming more prominent, the manifestation of such technology is still under high scrutiny given its computing process of "the black box" (Pasquale, 2015). It is important to gain a better understanding of how the technology arrives at certain decisions and why it takes such action. Determining liability for the AI case is a rather complex scenario. Some argue that the developers, operators or producers of AI should be held liable. However, in the future, AI-enabled robots may have greater capabilities to make decisions, learn, and gather experience independently of their developers, operators or producers; hence, it will be difficult to trace down the origin of the error to determine whether it stems from the improper decision by the system or it is caused by malpractice of the developers, operators or producers (Čerka et al., 2017).

Consequently, it is also going to be challenging in making a case under negligence. In Bolam v Friern Hospital Management Committee (1957), the Bolam test establishes the rule for assessing the appropriate standard of reasonable care involving skilled professionals in negligence cases which outlines that the standard required is by looking at bodies of professional opinion. The application of this test for Cobots will be extremely difficult given the involvement of multiple professionals and difficulty assessing the origin of the fault. Thus, arguing for developers, operators or producers' to be held accountable for a system that makes independent decision will rather be more difficult than it seems; hence, there is always a risk that no human will be responsible for what AI do (Wendehorst, 2020). Without the reasoning for action taken by the autonomous agent, there is an underlying problem for Cobots to be unaccountable in court, posing great challenges on regulators.

At the EU level, it has been an ongoing process to establish AI and robot regulations following the draft report on Civil Law Rules on Robotics (Mady Delvaux, 2016). During the process, the draft motion outlined to assign robot a legal status as one of possible legal solution to liability issues. However, a study commissioned by the European Parliament's Legal Affairs Committee to evaluate European civil law rules in robotic shows that it is not an appropriate solution to assign robot legal personality as that may lead to various unwanted legal consequences (Nevejans, 2016). Robots do not have consciousness, though having a legal personality often associate to mankind. Providing electronic person status would also mean that robots will be liable for their action and to provide compensation which may not possible. However, this term should not be confused with 'legal person' which can be assigned to a non-human object but that simply means representing self or others (but in the end there is a person (human) who backs up this term). Nevejans (ibid.) concluded that as robots are viewed as machines, it is appropriate for Directive 85/374/EEC to apply in the case of liability.

Nonetheless, the adopted resolution on Civil Law Rules on Robotics (2015/2103(INL), still suggests that *"creating a specific legal status for robots in the long run, so that at least the most sophisticated autonomous robots could be established as having the status of electronic persons responsible for making good any damage they may cause, and possibly applying electronic personality to cases where robots make autonomous decisions or otherwise interact with third parties independently."*(Civil Law Rules on Robotics, 2017, Section 59(f)). This requires further investigation for legislative instrument that is appropriate for AI-enabled robotics.

2.4.4 *Trust and Acceptance*

Trust and acceptance means something different from one group of stakeholders to another. In accordance to Lotz et al. (2019), where they conducted expert interviews with industrial workers and an online survey, for employer's perspective, an inherent problem stems from the lack of certainty in regulations. From employee's perspective, trust is related to the concerns about their safety to work alongside with robots and their job security that robots will take over their positions. For the former concern, as previously discussed above on the safety issue and solutions, adequate regulations on health and safety can help ease people's fears of being harmed by robots. However, it will take time for workers to fully adjust; the same mentality when meeting a new co-worker for the first time is also applied to robot-workers as stated by Frank Hearl, the U.S. National Institute for Occupational Safety and Health (NIOSH)'s chief of staff, "at first, you're watching the new person perform, and then as you see that they're doing their job correctly and safely over and over again, you build trust" (Vargas, 2018).

Secondly, the concern on unemployment has to be addressed. Robots may take over certain jobs but they will also create new jobs, although some of tasks that are replaced by robots are actually jobs that are not ergonomically best for humans or jobs that are undesirable to human workers or the ones that require high level of precision where errors can easily occur from human workers (Wallen, 2008; Pham et al., 2018; Vargas, 2018). Nonetheless, the periods known as industrial revolutions created a radical change in the industry, though, Bejarano et al. (2019) argued that this change can bring new opportunities and provide better living standards since the population could focus on areas with superior impact."

The introduction of new technology will significantly disrupt labour markets by eliminating certain jobs and creating new demand for change in workers' requisite skill sets. Education is one of the important solutions. There is a need to educate and prepare workers to undertake the higher-level jobs required by robotics. Training programs should be made available across the whole of the workforce whether the programs are implemented internally or co-funded by public–private partnerships for both workers who are still employed and those who are in between jobs (Bejarano et al., 2019). Potentially, it may require a national wide policy to enforce such programs in order to uptake the demand for new skills.

2.4.5 *Privacy and Cybersecurity*

Privacy is increasingly becoming a concern with robotics given its constant interaction with humans and its array of sensors, cameras, and microphones (Leenes et al., 2017a). In particular with managerial robots, they can be used as a tool for workplace surveillance. Some information captured by the robots about the employees can be considered as personal data and subjected to data protection laws. However, this is also a question to explore in the context of ethics of what data should be collected and analyzed? Consequently, it is the employer's responsibility to inform employees of this potential data collection and processing and also the robot designers and manufacturer to place certain safeguards in the design process to ensure the user's privacy is respected (Pinsent Mason, 2016; Boden et al., 2017). For example, data collected should only be kept for a limited time, hence, such rule should be reflected in the design (Regulation (EU), 2016/679, Article 5).

Also, another question to explore is whether should data only share with the manufacturer to help improve the product and should the data should be shared with the employers? There is a need for more research on the connection between privacy and robotics. One of the interesting research projects in this area is called "privacy-sensitive robotics." Scholars identify seven research themes as the keys for privacy-sensitive robotics research: data privacy; manipulation and deception; trust; blame and transparency; legal issues; domains with special privacy concerns; and privacy theory (Rueben et al., 2018). This creates a substantial road map for future research in this area. Nevertheless, privacy and cybersecurity issues are also applied to commercial sensitive data. Cobots will have access to internal information and insight into the manufacturing process. Should the Cobot cause a problem, different parties will have to determine who can access the data collected by the robot and how to best protect confidential information.

The contemporary debate in the field of robotics and the law is whether there is a lack of adequate regulation and a need for drafting new regulation specifically for robotics or the current regulation is sufficient enough (Hubbard, 2014; Leenes et al., 2017b). One of the potential solutions to settle this debate is a need for mechanism that match emerging technology to regulation and vice versa (Fosch-Villaronga and Heldeweg, 2018; Fenwick et al., 2016). Therefore, exploratory research and doctrinal research are required and will be discussed in the following Chapters. The exploratory research (Chapter 3 is conducted to identify the most crucial challenges in the context of Cobots that are present in the real world by interviewing professionals whose work are related to the areas of robotics, manufacturing, and/or implementation of emerging technologies in the workplace such as academic researchers, manufacturers, consultants, lawyers, etc. Whilst the doctrinal research (Chapter 4) investigated the applicability of the current law to Cobots.

2.5 CHAPTER SUMMARY

So, *what is a Cobot and its adoption challenges?* We have now established what is a Cobot in this thesis and its place in industrial workplace in this Chapter. Although this thesis only concerns robots in industrial space, we have introduced other sectors where robots are being used as this can help inform the policy and regulations surroundings Cobot adoptions in which we will discuss further in Chapter 4. We have unpacked the emerging term of Cobots which stands for collaborative industrial embodied autonomous systems to capture and outline the wide range of robotics types explored in this thesis from cleaning robots to trolley robots to robotic arms. The emerging term is derived from collaborative robotics discussed in literature, industry, legislation, and international standards. In addressing the contentious definition of Cobots, we have explored the root of the term and its limitation which enables us to identify the need to further clarify the basis of this technology to capture the subject matter of this PhD thesis. Consequently, we recognise the future of Cobots and the need to apply future studies method to create a complete picture in understanding the adoption challenges and implications of this technology on regulations. After establishing what Cobots are, we investigate the potential challenges and implications on the adoption of this technology ranging from the debate on job displacement to safety concerns to legal implications. We are aware that given the contentious definition of Cobots, the adoption challenges are varied depending on the types of Cobots. Through this process, it becomes clear that there is a limited literature in exploring the challenges and implications of this technology as the literature mostly discusses the challenges predominantly related to Cobots in a form of mechanical arms. Therefore, this Chapter forms the basis for the topics to be explored further in Chapter 3 to understand the adoption challenges of Cobots.

3

EXPLORING COBOT ADOPTION CHALLENGES IN INDUSTRY

Is it technology or is it really the law?

Contents

3.1 CHAPTER OVERVIEW

In addressing the definition challenges, we have demonstrated in Chapter 2 the need to form a new terminology which is specific to human-robot collaboration in the industrial workplace while being generally broad enough to ensure it captures all relevant types of robots. As a result, we redefined the term 'cobot'. Following this background, Chapter 2 provides an overview of the challenges and implications of Cobot adoption discussed in the literature ranging from socio-economical debate to safety to liability to privacy. However, these challenges are mostly discussed in the light of Cobots in the form of robotic arm. Therefore, the lack of literature in the space of Cobots might lead to a far-removed analysis from what is happening in practice. Facing with this limitation, in this Chapter we took on an empirical study to investigate the challenges from the practice perspective from professionals who are knowledgeable in technology adoption, particular autonomous systems, to gain realistic analysis of the current circumstances and understand the relationship between law and technology adoption challenges. We recognise that Cobots are not yet fully adopted or used as intended in the manufacturing sector, and the future of this technology is still in development. To address this factor, we include Cobots as part of Digital Manufacturing Technologies as outlined in Chapter 2 providing the similar characteristics of Cobots to other technology that are more widely adopted.

For the empirical study, semi-structured interview method is deemed to be most appropriate to gain industry insights and understand the challenges from the perspectives of experts ranging from manufacturers[1] to lawyers to consultants to technologists with most of the ex-

1 Manufacturers referred to in this PhD thesis is in the view of robot adopter as opposed to robot manufacturers. We recognised that this could be confusing providing that the robot manufacturers also have certain associated risks and liability in supplying robots, however, in this PhD thesis context, we focused on adoption barriers. Therefore, when referring to the provider or the maker of the robots, we consider this group of stakeholder as technology designer or developer.

perts having more than 15+ years of experience in the field relevant to technology adoption. This study reveals the future of human-robot collaboration, its impact on how businesses operate, how the regulation is applied and perhaps needs to be updated, and how people will interact with their work environment and demands. The analysis of challenges and implications are categorized under ten themes: adoption of new technology, trust, risk, safety, due diligence, regulatory, ethics and social challenges, data and privacy, design, and insurance. Some of these challenges overlap with the factors pointed out in the literature review while some of themes highlight the emerging problems as well as address some of the controversial debate such as job displacement due to Cobot adoption.

Furthermore, to ensure the rigor of the findings, we collaborated with our research partner, DigiTOP, on a survey study (Section 3.2.2) to understand broader stakeholders' perspectives in particular end-users (i.e., manufacturing employees). The survey mainly draws upon the findings in relation to three themes: adoption of new technology, trust, and data and privacy as these are also highly interesting to our research partner. The analysis of the survey is supported by our colleagues who are expert in quantitative analysis providing that this is not our field of expertise. The survey findings echo the findings from the expert interview study from the positive reception on the uptake of Cobots considering the potential benefits to potential impacts of the technology. It is recognised that digital manufacturing technologies like Cobots are predicted to free workers from mundane and repetitive jobs to focus instead on more joyful, interesting, and rewarding tasks. This is reflected in the survey how adoption of DMTs can increase well-being of the workers such as reduced levels of stress, fatigue, monotony, anxiety, physical workload, safety concerns, and occupational diseases.

The findings weave in together the analysis of both qualitative and quantitative studies (hereinafter referred to as 'the Study') to present the challenges and implications of DMTs and Cobot adoption. The results from the Study address the challenges and implications beyond Cobots and present points for considerations in the future of technology adoption. Although Cobots are the core of this thesis, we found that the expansion of the research scope to other DMTs does not take away the focus from Cobots. Rather, it provides an introduction to wider implications of Cobots as part of the digital technology ecosystems and lessons learned of previously implemented technology applicable to Cobots.

3.2 METHODOLOGY AND METHODS

Is the frequent reference to "cobots" a marketing buzzword? It is and it is not. Marketers often make Cobots sound smarter and better than they are. In the manufacturing world, Cobots are referred to as robots or an autonomous system with physical attribute that are safe to work in the same environment with human workers without any barrier. Similarly to industrial robots, there are various types of Cobots for different purposes. It is important to note the difference between industrial robot, or 'dumb machine' to autonomous robot. We find that confusion is often caused by the difference in terminology between 'automated machine' vs 'autonomous machine.' An automated machine is a machine that runs on simple programming, can do things automatically, but follow strict steps (i.e., the machine is doing only one single task/motion) whereas autonomous machine as the term suggested, the machine has certain degrees of autonomy and the ability to adapt to new conditions. Although, the contentiousness of the definition of Cobots has already been addressed in Chapter 2, however, this challenge is one of the motivations and reasons that an exploratory research approach (Stebbins, 2001) was chosen to explore the legal, social, and ethical challenges of the implementation of collaborative industrial embodied autonomous systems (Cobots). This term at hand is full of unknowns and carries a certain level of complexity. In order to truly delve into the topic and understand it thoroughly, a high degree of flexibility and creativity is needed in terms of research such as formulating a new definition for a certain term or finding new and innovative ways to examine the concept. As Stebbins (2001) stated,

> *Exploration is no place for data collection formulas distilled from conventional theory and methodological practice. On the contrary, exploration is where the art of science is most widely exercised, the area of science where imagination reigns most freely. Creativity in this domain comes through inductive reasoning, as researchers discover order in what initially appeared to them as chaos.*
>
> — Stebbins (ibid., p. 22)

As addressed in Chapter 2, the literature on Cobot adoption is limited and therefore a further investigation is required. Given this background, there is also limited knowledge in Cobot adoption from different sectors. Therefore, we situated Cobots as part of emerging digital manufacturing technologies (DMTs) as they share similar characteristics of use of sensors and data analytics for machine operations. Some of the DMTs such as VR, AR, and Digital twin are of high interest in manufacturing sectors and easier to integrate than Cobots which made these technologies more adopted than Cobots at present. We use DMTs to set the scene for the exploratory study where technology is more familiarised by the industry. By presenting the similar characteristics to Cobots, this enables us to build on this narrative in exploring Cobot adoption.

Therefore, to understand the legal, social, and ethical challenges of the implementation of collaborative embodied autonomous systems in industrial setting, we need to gain the perspectives of different experts involving in the technology development and implementation such as manufacturers, lawyers, consultant, technologist, and academic researchers, thus qualitative approach is viewed to be most appropriate to investigate people attitudes and concerns. We found expert interview approach to be the most suitable method for the purpose of this study which is which is to gain in-depth insights from different experts involved in technology development and implementation and their outlooks on the subject matter (Bogner et al., 2009).

Following the qualitative data collection performed via interviews to capture the depth of attitudes and opinions about industrial collaborative robots, we wanted to explore whether these opinions could be generalized to the population level. Therefore, we worked with our industry partner, DigiTOP, on a survey study to gather experiences of people working with digital manufacturing technologies (DMTs) to inform us on the acceptance and adoption of industrial collaborative robots and other DMTs in British manufacturing. The survey questions (see Section A.7) focused on the opinions expressed by the participants in the interview stage and provide inferential statistics to give further insights about DMTs adoption. We addressed different stakeholders working within UK manufacturing companies such as operators, production managers, production technicians, engineers, maintenance technicians, quality inspectors, Human Resources personnel, middle management, senior management, and CEOs. The survey by design focuses more on the general adoption and acceptance challenges which we found to be most benefited from quantitative study in order to validate the more general concerns of the adoption. However, specific challenges such as legal implications benefit more from an in-depth discussion with experts.

In weaving together of both qualitative and quantitative studies, we present the challenges and implications of DMT and Cobot adoption. The results from this empirical research address the challenges and implications beyond Cobots and present points for considerations in the future of technology adoption. Although Cobots are core of this thesis, we find that the expansion of the research scope to other DMTs does not take away the focus from Cobots but rather an introduction of wider implications of Cobots as part of the digital technology ecosystems and lessons learned from previously implemented technology applicable to Cobots.

3.2.1 *Qualitative Study: Expert Interview*

3.2.1.1 *Recruitment*

The participants were recruited using the snowball sampling method. As Sadler et al. (2010) described,

> The snowball sampling outreach strategy finds individuals (the "source," also referred to as the "seed"), who have the desired characteristics, and uses that person's social networks to recruit similar subjects, in a multi-stage process. After the initial source helps to recruit respondents, the respondents then recruit others themselves, starting a process analogous to a snowball rolling down a hill.
>
> — Sadler et al. (ibid., p. 2)

To start, emails were sent to colleagues and project partners to help distribute the recruitment request to potential participants who are experts in fields relevant to the implementation of emerging technologies, particularly robotics. As experts are often networked people, many of the participants were recruited through their connections. Because we set a clear objective that participants would be asked about the current challenges and emerging potential ethical, legal, and social risks in implementing digital manufacturing technologies, particularly human-robot collaboration, we only pursued participants that were, to a certain extent, involved in either decision-making related to the development, and/or implementation of digital technologies, and/or acting as expert advisors for companies, and/or governmental agencies, or involved in establishing robotics and AI standards. As a result, we were able to obtain a well-mixed sample of professionals in different roles and from a variety of industries providing a broad picture of the topic. A total of 15 professionals participated, consisting of practitioners, and researchers: three manufacturers, five lawyers, two technologists, four technology and business consultants, and one robot ethics researcher (see Table 3.1 for the participant's expertise. For more detail see Section B.1). The interview study was conducted between May 2019 and July 2020. It is acknowledged that a minimum of 12 participants is recommended for qualitative studies to reach data saturation. The analysis showed that the prominent themes emerged after 10 participants. New codes were identified from the 11th to 15th participants, however, they only added to the existing themes, demonstrating that data saturation was reached. Therefore, the sample size of 15 participants was deemed sufficient for the qualitative analysis of this study and further recruitment was not required.

UNIQUE CODE-NAME	ROLE IN ORGANISATION	YEARS OF EXPERIENCE IN THE ROLE	AREA OF EXPERTISE
P1T	Deputy Director	30	Robotics and autonomous systems
P2M	Quality Director	15	Automotive industry—quality control
P3T	Chief Technology Officer	20	Quality management, software, artificial intelligence, standards development
P4C	Founder and Director	15	Privacy, data protection, public policy
P5R	Senior Researcher	4	Human centred computing

Table 3.1: Participant Expertise (Codename: T—technology, L—law, M—manufacturer, C—consulting, R—research)

UNIQUE CODE-NAME	ROLE IN ORGANISATION	YEARS OF EXPERIENCE IN THE ROLE	AREA OF EXPERTISE
P6C	Consultant	39	Digital technologies, social responsibility, sustainability, and ethics; organisational behaviour; standardization
P7L	Research and teaching	24	Law and technology
P8L	Partner	23	Law and connected autonomous vehicles
P9C	Director	5	Connected and automated vehicles, Technology commercialisation
P10C	Founder and Owner	30+	Connected and autonomous vehicles infrastructure
P11L	Director (senior lawyer)	18	Law and connected autonomous vehicles, specifically transport regulation
P12L	Senior Associate	8	Law, technology, and data

Table 3.1: Participant Expertise (Codename: T—technology, L—law, M—manufacturer, C—consulting, R—research)

UNIQUE CODE-NAME	ROLE IN ORGANISATION	YEARS OF EXPERIENCE IN THE ROLE	AREA OF EXPERTISE
P13L	Professor	7	Law and technology
P14M	Innovation Manager	20	Manufacturing
P15M	Projects	30+	Automation

Table 3.1: Participant Expertise (Codename: T—technology, L—law, M—manufacturer, C—consulting, R—research)

3.2.1.2 *Procedure*

The Computer Science Research Ethics Committee of the University of Nottingham approved the interview study (CS-2018-R48). Participants were given an information sheet and a privacy notice form that addressed how their data would be handled (see Section A.1 and Section A.2. Participants signed a consent form before the study began. Participants were asked to fill out a survey (see Section A.6 to capture their background and expertise, as well as their experience with technology and their knowledge of Cobots. We chose a semi-structure interview approach, using a conversational style of interview as well as open-ended interview questions (see Section A.4. The participants were asked about their background, expertise, their understanding of Cobots, and their opinion on the legal, ethical, and social challenges of emerging technologies, and the general concerns or challenges in adoption of emerging technologies. The emerging technologies include smart embodied autonomous systems for the application of human-robot collaboration. As some participants were not extremely familiar with manufacturing industries, we used the term 'workplace' to provide a context for human-robot collaboration to avoid bias of the conventional manufacturing setting. We are interested in collaboration of all levels, as discussed in Chapter 2, from physically interaction to merely existing in the same space e.g., a robot cleaner or traditional 'cobot' without a cage. The study uses the word 'emerging technology' as a conversation starter as people are more familiar with the term. Such technology refers to, amongst other technologies, AI, robotics, self-driving cars, and smart IoT devices. The common characteristics that these technologies shared is the utilization of an autonomous system i.e., the system makes the decision on its own whether that be making stock exchange, putting thing in a package, or adjusting house temperature. Therefore, the inputs regarding these emerging technologies are highly relevant and applicable to Cobots.

Following this narrative, the interview questions are twofold: general questions on emerging technologies and Cobots specific questions. As it is acknowledged cobot is not a definitive term, we used vignettes (Finch, 1987; Hazel, 1995) (see Section A.5 as a complementary research technique to the interview study to help inform interviewees of what Cobots are and the future of this technology to create the basis of the Cobots in discussion. This approach helped create a common familiarity with Cobots amongst the participants and allowing for more in-depth discussion providing that the interviewees are more informed of Cobots specified in this thesis. All participants were assigned a unique number and an acronym to identify their expertise, e.g., P1M is a participant who represents manufacturer (T—technology, L—law, M—manufacturer, C—consulting, R—research). Each interview lasted between 45 min and one hour.

3.2.1.3 *Analysis*

We used Nvivo 12 software to organise the material and followed Braun and Clarke (2012)'s thematic analysis approach to analyse the data and identify themes concerning the research questions. We followed their six-phase approach to thematic analysis: (1) data familiarization; (2) generate initial code; (3) code clustering; (4) review potential themes; (5) define and name themes; (6) produce report. Accordingly, an inductive coding approach was chosen to analyse the data. Inductive coding refers to a process where themes are inductively defined from the codes based on the raw data being explored without drawing from any predetermined or theoretical constructed framework. We found that inductive coding allowed us to further explore the data and uncover some challenges that we were not aware of. The codes are either descriptive or interpretive (Braun et al., 2016). As we followed the inductive coding approach, we found key challenges beyond what are categorized under legal, ethical and social challenges as specified in the research question. The ten themes were formed based on 62 codes. The ten themes are: adoption of new technology, trust, risk, safety, due diligence, regulatory, ethics and social challenges, data and privacy, design, and insurance. (see Table 3.2 and see Section B.2 for further illustration of selections of codes, descriptions, and examples)

THEME	CODE	DESCRIPTION	EXAMPLE
Adoption of new technology	Acceptance of new technology	Elements that influence people to accept or not accept new technology (user perspective)	P14M: "We have got various systems and those operations automated with robots. People tend to take those quite, quite well. Jobs that are boring and monotonous then people will choose not to do to be fair. And particularly it's cold in our factories."

Table 3.2: Description of Code

THEME	CODE	DESCRIPTION	EXAMPLE
Adoption of new technology	Change management	Approaches that can help prepare, support organisations in adopting new technology	P2M: "I will say in our activity, we have no issue with that. In fact, nobody has gotten fired. And this is why it's easy for us just to explain what we want to do and what are the reasons such as our company will be more profitable. They are not afraid that they will be fired."

Table 3.2: Description of Code

THEME	CODE	DESCRIPTION	EXAMPLE
Design	Design of robot	The characteristics of robots and design process that can help with the adoption of this technology	P1 Technologist: "I think that there are a whole pile of technological problems or challenges to overcome... not to the same degree that humans have, but clearly, that ability to be more dexterous in manipulating objects and the ability to be able to cope with the fact that the situation isn't always exactly the same."

Table 3.2: Description of Code

3.2.1.4 *Validity*

We acknowledged the debate of the best approaches to ensure validity of the results and that it still has not been settled for a definitive answer to this issue (for detailed discussion on different approaches see (Virginia, 2013)). However, we made sure that the analysis was done systematically with rigorous checking on the findings and present the

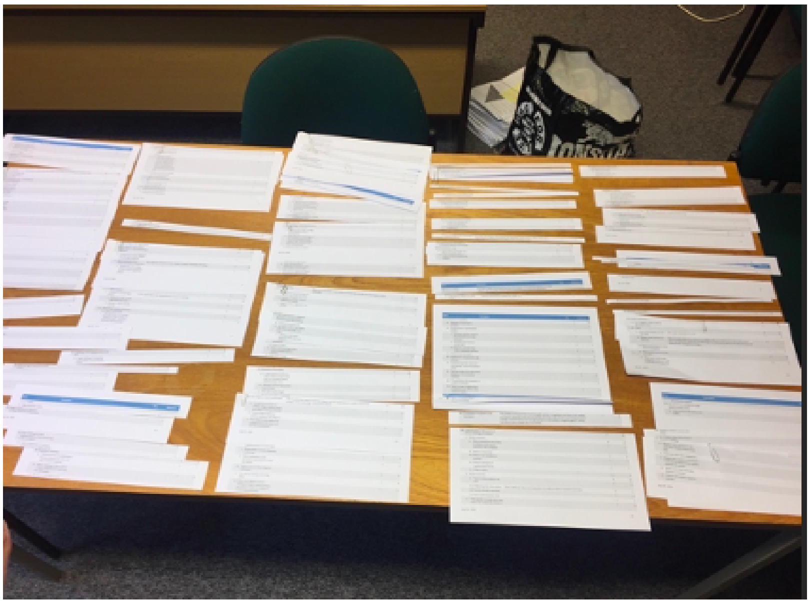

Figure 3.1: Analysing Codes

analysis steps in detail as possible. Therefore, an iterative process was taken three times. We performed the first code clustering (Braun and Clarke (2012)'s Phase 3) based on the first six interviews. With each new analysed interview, more codes were formed; therefore, we repeated the code clustering process after the 10th transcript and again after the 15th transcript. We used the existing codes against new transcripts to ensure that all themes are covered, and no new themes emerge to verify the initial classification of codes.

Consequently, we conducted a triangulation process whereby two researchers with different backgrounds (law and computer science) separately performed the coding process of 30 quotes. The quotes were coded in a similar manner by both researchers, thus, validating the reliability. Finally, three researchers performed Braun and Clarke's Phases 4 and 5 together to define and discuss relevant themes (see Figure 3.1 and Figure 3.2).

Figure 3.2: Define and Discuss Themes

3.2.2 *Quantitative Study: Survey*

3.2.2.1 *Recruitment*

We used the recruitment platform Prolific Academic to recruit participants. The platform offers the opportunity to filter certain demographics to pre-screen the participants. In our case, we needed UK participants working in manufacturing. The platform allowed us to easily integrate our Qualtrics survey tool and collect our data between 14 and 15 October 2020. Participants completed the survey online, which was timed to take no longer than 12 minutes. The survey was organised in three parts. The first section investigated the perceptions on digital manufacturing technologies. In the second part, employees who worked in organisations that use DMTs such as robots, virtual reality, or sensors were questioned about their actual experiences with these technologies and other related issues. In the final section, the participants provided demographic information.

184 participants were recruited; 129 were male, 54 were female, and one did not indicate their gender. The majority of the participants were either from the age groups of 25–34 (31.1%) or 35–44 (31.1%);

45–54-years old represented 18.6% of the sample, and 12.6% were in the 55–64 year range. Only 6.6% of participants were from the age group of 18–25. Participants work in different manufacturing industries (27.2% transportation, 16.8% metal and machinery, 12% food and beverages, 10.9% electrical/electronics, 9.8% plastic and chemical products, 6.5% wood, leather, or paper, 5.4% clothing and textiles, 5.4% medical/pharma/cosmetics, and 6% indicated that their industry was 'other'). We also asked participants about their role in the company and initially had 13 answer options. These roles were condensed into three main roles: 50.6% shop floor workers (i.e., operator, production manager, production technician, engineer, quality inspector, maintenance technician), 44% managerial roles (i.e., middle management, senior management, CEO) and 5.4% customer facing (customer service, marketing, sales), with an average of 8 years (STD = 6.9) in their current position. The survey sample had an uneven distribution of company size, with 19% of participants working in small companies (<100 employees), 29.9% working in medium sized companies (100–500 employees), and 51.1% working in large companies with over d employees. Over half of the participants had a college or university degree (57.4%), 21.3% had secondary or further education, 18.6% had a post-doctoral degree, and 2.7% had secondary school up to 16 years of education.

3.2.2.2 *Procedure*

As the survey was in collaboration with our research partner, DigiTOP, Cranfield University's Research Ethics System (CURES/12146/2020) approved the research. Each participant provided informed consent prior to taking part in the study.

3.2.2.3 *Analysis*

The collected data were exported to SPSS Statistics 26. We checked the data for complete responses and completion time. The data from incomplete responses or or completion times of shorter than 3 min were discarded. The first step for the data analysis was an overview of the participants' responses as a whole group. A non-parametric Wilcoxon signed rank test with hypothetical median of 3 (middle score on all answer options) was used to establish whether participants' responses differed significantly from the neutral answer option. Following this, we compared shop floor employees with managerial employees with a non-parametric Mann-Whitney test for two independent samples.

3.3 RESULTS AND DISCUSSIONS

The Study confirms that contentious discussion of cobot definition and reveals the 10 challenges inhibiting the mainstream adoption of the emerging technology by businesses: adoption of new technology, trust, risk, safety, due diligence, regulatory, ethics and social challenges, data & privacy, design, and insurance. Upon exploring these themes, we have create a framework for Responsible Cobot Adoption Principles (see Figure 3.3). We find data privacy to be at the core of the adoption challenges which we will demonstrate throughout the findings discussion in the following sections and in Chapter 4. Figure 3.3 demonstrates how the themes are weaved in together to reflect the fundamental factors for responsible Cobot adoption in 3 different layers. The most inner circle layer represents the interconnections of the fundamental technological requirements as well as the guiding principles that adopters must consider. In the second layer, by meeting these principles in the first layer, it can help in cultivating a sense of trust, assuaging concerns pertaining to potential harm caused by robots or the fear of replacement. Lastly, the aim is to gain acceptance from different stakeholders including employers (who decide to invest in cobots) as well as employees who will directly interact with these robots.

We acknowledge that the individual themes within the framework are not discussed by the experts equally, providing a breadth of rep-

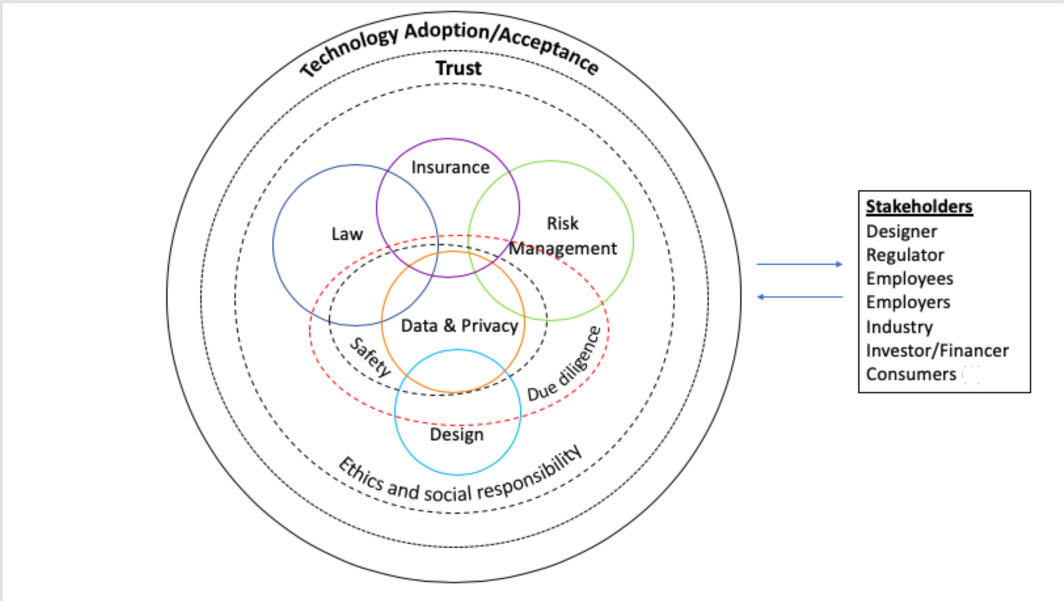

Figure 3.3: Framework: Responsible Cobot Adoption Principles
(from design to development to deployment)

resentation of the themes. Some themes are discussed in more depth, including but not limited to, the adoption of new technology, regulatory issues, data & privacy, and design challenges, whereas other themes might be viewed as the bridging themes between the more highlighted themes. For example, theme 6 insurance, deals with both safety and regulatory challenges. Nonetheless, the importance of the individual themes should not be judged based on how extensively they are discussed. In essence, each theme of the challenges could be viewed as an independent factor that needs to be addressed, but in retrospect these challenges should be considered simultaneously in different stages of technology from design to develop to adoption of Cobots.

Furthermore, the findings are particularly interesting as the themes also confirm similar results to a study by Kildal and others, in which they identified key concerns and attitudes towards collaborative human-robot system (Kildal et al., 2018). Their results showed that lack of knowledge as first reason followed by workers' acceptance then cost, and regulation came as the fourth main barriers for the adoption of Cobots. The study views Cobots as collaborative robots, a type of robots which enables human-robot collaboration and has the ability “to work with humans in close proximity or even in direct physical contact with each other" (Kildal et al., 2018, p. 21). Kildal and others conducted a workshop with 100 professionals who were already users of collaborative robotics or were considering introducing them in their processes in the future from industry participated. Thus, it is unclear whether (and how) the study reflects the perspective of different stakeholders. However, as the term ’cobot’ was used loosely in this study with a case study of cobot as robotics arms, therefore, the scope of the study by Kildal and others is narrower than the scope of Cobots described in this thesis, and it could be expected that more challenges and implications are left undiscovered.

Moreover, the findings in the Study demonstrate that to have a complete picture of the adoption challenges, we will also need to explore the challenges start from the development of technology for the following reasons:

- Firstly, answering to what businesses want is difficult due to technology limitation and lack of stakeholders’ involvement;
- Secondly, the product has to be ‘safe’ although this is the minimum requirement and all products are, in theory, capable of safe use. However, with new technologies, there are not enough evidence that they are safe which makes risk assessment for technology implementation difficult;
- Thirdly, industry experts viewed that the lack of clear guidelines on liability deters Cobot adoption. To overcome this, we need to address the following dilemma. The law could help in gaining confidence, but it cannot take a stand until there is enough product or demand in the market. However, the reason why technology is not available in the market is due to the fear around to adoption given. So, without the support and demand of the market, there is no product and therefore the regulators do not have enough incentives to regulate the technology and study its impacts.

In addition, following the discussion around challenges, the interviewees also provide recommendations on the solutions to overcome some of the pain points of Cobot adoption. We noticed that challenges under one theme also be addressed through a solution for other challenges which we will dive further in the following sections. To provide the overview of the 10 themes and the sub-themes (i.e., contributing factors), Table 3.3 below presents the themes which categorize different challenges and implications of the implementation of the emerging technology and the uptake of DMTs including Cobots by businesses. The table data are not presented in any specific order nor the level of importance or impacts of the challenges in Cobot adoption.

THEME	FACTORS
Adoption and acceptance of new technology	Change management; suitability to business model; cost; proving improvement in efficiency and productivity
Trust	Collaboration requires trust to a certain level; need for accountability, transparency, and explainability of the robot to form trust; trust is irrelevant in the workplace setting due to a lack of choices
Risk	Determining what is the acceptable risk; acceptable risk is contextual; how to perform the risk assessment and manage the risk; risk allocations through contractual arrangements can be difficult depending on the business bargaining power
Safety	Safety protocol is difficult to establish; currently keeping humans and robots separated; risks have to be minimized while allowing robots to be functional; a minimum requirement for product commercialization and implementation; determining how safe is safe enough is still a challenge

Table 3.3: Description of Themes and Factors

THEME	FACTORS
Due diligence	Rushing to the market without an adequate level of testing; lack of involvement of different stakeholders; proving the degree of product reliability; need for stricter rules on due diligence
Regulatory	Lack of regulatory framework and guidelines; questioning the current framework and its suitability to govern the implementation of emerging technologies; need for more harmonized regulatory instruments, whether that be legislation or standards; law hinders innovation; liability and responsibility gap; data protection vs. data ownership; bridging the gap between science and law
Ethics and social	Ethics at the core of implementation; job displacement vs. change in current role - economical vs. ethical concerns; environmental impact; robots change work environment and their roles; ethics in tech is contextual – same technology can have a different purpose of use and design
Data and Privacy	Understanding different types of data being collected and stored by the robots; privacy of employees as fundamental rights
Design	Technical challenges/limitations - dexterity, handling ability, and cognitive process; guaranteed safety while meeting functional requirements; a lack of human factor in design by expecting the operator to be perfect without considering differences of users; bias within the system due to training data; design ethics - how much control should the robot have, 'explainability'; challenge to program ethical robotics; making ethical judgements is just hard because humans do not have it figured out
Insurance	Insurance will be fundamental; increased premium price

Table 3.3: Description of Themes and Factors

It should also be highlighted that all participants have experience working with some form of autonomous systems, providing them with a foundation and knowledge to offer informed comments on the adoption of Cobots, including the speculative nature of this type of robots. For example, experts in law (L) and consultants (C) have collaborated on projects with technology designers and providers to examine the regulatory challenges of technology, as demonstrated in the 'Area of Expertise' section of Table 3.1. Additionally, experts in technology (T) and manufacturing (M) have direct interaction with the design and deployment of technology, particularly in AI and robotics. As a result, the responses by experts are grounded in their practical experience and thereby validating their contributions to the themes and recommendations.

Moreover, as addressed in Section 3.2.1.3, we chose inductive coding thereby the codes are descriptive or interpretive. In presenting the findings and the discussion, we first start with the definition of Cobots. Interviewees are required to fill out a survey as described in Section Recruiting, the survey results confirm our argument on the contentious definition of Cobots. In exploring the findings, the ten themes uncover some of the very common debates, such as, the impact on employment and safety issues of Cobots. The findings also present surprising results such as how the adoption challenges can stem from lack of understanding of the technology which leads to over expectations or unnecessary fears of the technology. In the following sections, we will present the themes in depth, how they intertwine, and the insights we draw from the Study to paint a complete picture of Cobot adoption challenges and implications.

3.3.1 *Cobot Definition*

Firstly, as mentioned in Section 3.2 and Chapter 2, the definition of Cobots is still debated but the two distinct characteristics of Cobots are that they are safe to work along humans and have certain degrees of autonomy. These characteristics are generally reflected in cobot definitions given by the participants as shown in Table 3.4. Overall, participants seem to view a cobot as an additional part of the workforce where the technology will be working with human workforce for better task results and to improve working conditions. Furthermore, we also saw a new perspective from robot ethics expert P5R who approaches Cobots as robots working together rather than human-robot interaction. This suggests that the term 'cobot' is still at its nascent stage and therefore the impacts of this technology might not be fully realised until it is more adopted by the industry.

PARTICIPANT	COBOT DEFINITION
1T	Robots that work with us and amongst us to *improve the quality of our lives*
2M	Industrial automatized robot able to work in a human environment in a *safe way*
5R	Robots (for the workplace) that have to collaborate with other robots in order to accomplish their tasks
6C	Dangerous until we get the behaviour correct and embedded with a first *do no harm* mandate
7L	Programmable machines with sensors and affectors that interact to a *degree autonomously* with their environment, and where the environment contains humans that interact with the robot
8L	Nodes within an interactive system without linear conventional control dynamics
11L	Robots that are used to *work in conjunction* with humans for tasks

Table 3.4: Cobot Definition Described by Experts

PARTICIPANT	COBOT DEFINITION
12L	Robotics designed to work alongside humans in a collaborative way to deliver measurable benefits (e.g. efficiencies)
13L	Either where multiple robots work with one another, or as robots working *alongside humans* (aka co-robotics)
14M	Robots working *unguarded* alongside humans
15M	*Working with the human* rather working for the human

Table 3.4: Cobot Definition Described by Experts

3.3.2 *Theme 1: Overarching Adoption and Acceptance of New Technology Factors*

From the start, why should industry adopt Cobots? The manufacturing industry continues to grow and thus requires more human capital and advanced technologies to cope with the increase in demand and emerging markets (Manyika et al., 2012). Certain manufacturing sectors are finding difficulty in filling emerging roles due to a low level of interest from suitable candidates. For instance, employing new shop floor workers is challenging because manufacturing tasks tend to be mundane and repetitive, and therefore unattractive to employees. Thus, manufacturers resort to the adoption of new technologies such as collaborative robots to cope with the labour shortage and maintain production quotas. However, many manufacturing sectors struggle to attract highly skilled labour and compete with other industries for digitally skilled employees. At the same time, the introduction of new technology causes current employees to fear the loss of their jobs because they do not possess the right skills and experience to supervise and maintain the machines. These contradictory issues of having to acquire new technologies to solve a labour shortage, while also having to let go of unskilled labour is an employment paradox emphasized by our study. This theme also discusses the key factors experts found to be use in decision-making for such technology investment and the implications of the adoption including cost vs benefit analysis, the technology expectations of technology, and the acceptance factors of Cobots. It is also important to note that when referring to 'adoption' it is rather from the employer's perspective whilst 'acceptance' represents the view of the users i.e., the employee who will be interacting with the Cobot.

3.3.2.1 *Technology as a Solution to Labour Shortage*

Manufacturing industries are experiencing a shift in the workforce. One of the key reasons that motivate firms to innovate and adopt emerging technology is labour shortage. Our interviewed experts cited the difficulty in recruiting and retaining employees due to the unattractive working conditions of manufacturing plants. Research found that people do not want to perform tasks in the final assembly lines of car manufacturing because the tasks are repetitive, physically demanding, and often result in several costly health problems (Boavida and Candeias, 2021). From our expert interview, innovation manager P14M describes a similar experience where people choose not to do jobs that are boring and monotonous, especially in cold factories. The expert continues to explain that the manufacturing industry does not appeal to the next generation and, because the current workforce is heading towards retirement, their organisation considered Cobot adoption as a solution to cope with industry expansion and labour shortage. As the innovation expert puts it,

> *We've got people who have got the clock card number 007 and the lady was very proud as she was the seventh employee. She's been there for 25 years, but with that comes the other risk that those people are going to be retiring in the not too distant future*

> *[. . .] and our labour pool is restricted because of low unemployment in the area [...] we have a turnover of staff that is challenging to keep the feed. We see automation as a way to supplement our recruitment as well as maintain the number of people that we need because we're growing as well*
>
> — P14M, Innovation Manager

The innovation manager also emphasizes that technology is brought in to do tasks that people do not want to do rather than to replace the current employees, *"We have demonstrated that over the years we actually tend not to bring automation to reduce the amount of people overall. Those people are distributed somewhere else to do jobs that are actually a little bit more interesting or in a more pleasant environment."*

When we visited the food factory where we interviewed P15M, we noticed that the production lines were predominately human led. However, this will likely to change due to labour shortage as highlighted by Robotics and Automation Expert P15M *"You've seen number of people that we have on lines, the volume for this business. we have issues getting labour, particularly in Christmas. Last year, we couldn't run the lines for the length of time that we wanted, because we just physically couldn't get the people to do it."* The labour shortage is expected. According to a report conducted by Deloitte and Manufacturing Institute, in the US it is predicted that over the next decade more than 2.6 million baby boomers (born between 1946 and 1964) are expected to retire from manufacturing jobs despite the trend of delaying retirement. This could lead manufacturing sector to face a demographic challenge to attract new employees as there is "negative perception of students/their parents toward the manufacturing industry" (Giffi et al., 2018). Hamper (2008), the author of Rivethead, also provided good insights into the working conditions in the automobile assembly line during the 70s-80s. Although this work was written to depict the condition of over 40 years ago, we made a recent visit to automobile factory and, whilst the working conditions have improved since the time of the memoir, the environment, especially with the noise, and repetitive nature of tasks described by Hamper are still the case.

3.3.2.2 *Lack of Skilled Labour*

Although manufacturers are moving towards robotics and automation as a solution to combat labour shortage, many manufacturing companies find the lack of skills a serious limitation to their ability to implement DMT technologies and practices. The increased prevalence of digital technologies within workplaces is dramatically altering the demand for certain skills, with employers requiring operational staff to have a wider knowledge of different technologies and production methods (Vivian et al., 2016). Organisations need employees with specialised skills, which may be difficult to find. For many organisations (in particular SMEs), it is too costly to innovate in-house given that the need for such skills is specific to certain technologies and projects (Bughin et al., 2022). When introducing new technology to the workplace, it is expected that a company hires employees with different skills, or trains their existing workers to acquire these new skills. Quality control director P2M explains that within their own organisation, new talents need to be employed because current workers lack the expertise to deal with advanced machines such as Cobots. P2M sees some challenges training current operators to control machines and be able to problem solve on the spot *"I'm not sure if they will have the expertise in dealing with Cobots but they need to know how to conduct a good analysis to find the part that fails. The challenge will be to have a good explanation to the operators and to train the operator that would be working in this environment"*. However, some of our experts state that if the introduction of a new technology is minimal it may not be economical to have such expertise in-house. As explained by autonomation expert P15M, *"For a robot, you teach it the fundamentals, but if you change from fundamentals, then you've got to reteach it. It's a very expensive skill that you need to keep in house. If you have two or three robots, you wouldn't necessarily have that skill because it's not worth it."*

Organisations cannot expect to be able to extract the full capabilities of advanced machinery merely by installing them correctly and “flipping the switch”. One also needs to look at the effectiveness of use, as there will be inevitable operational problems when adopting new technologies (breakdowns, adjustments, debugging). Economic geographer Gertler explains that “machinery and production process innovations are often so complex that successful implementation post-adoption cannot be assumed” (Gertler, 2004, p. 26). Our survey showed that there are indeed many operational problems to deal with and issues requiring adjustments (84%) after implementing DMTs, such as hardware (47%) and software failures (52%). Often the technology is under-utilized (37%), misused (9%), or avoided altogether (15%). Gertler determines that there is a need for much greater emphasis on worker training, given a tendency for Anglo-American firm owners to under-invest in this important function relative to their European and Asian counterparts (ibid.). Employers see a clear need for operational staff to have wider knowledge and understanding of different technologies and production methods (Vivian et al., 2016). Industry 4.0 also requires this knowledge to be continually developed with periodic training every few years to renew and expand skills (Sima et al., 2020; Ali et al., 2019). Surprisingly, we found that people who have not yet worked with digital manufacturing technologies in their organisation feel that they do not need to acquire new skills to be able to work with these innovations. This is in contrast to employees who already have experience with these technologies.

In addition to training and/or hiring workers with skills required at the level of programming and maintaining technology, another crucial point to address is that organisations will need to maintain employee satisfaction so that they stay in their jobs. About a third (35%) of DMT users participating in our survey noted workforce dissatisfaction with the new technologies. As a robotics and Robotics and Automation Expert P15M puts it, *“as you start getting a mass [referring to robots], how many people do you train? And how do you maintain the* *interest for that level of labour, that expensive labour?"* Similarly, the innovation expert P14M noted that the industry is not very attractive and has a high turnover rate. Skilled workers may leave the job easily, so it is important that employees are engaged and remain interested in their work.

Nonetheless, although new skills are required to work with smart technologies, in some roles the skills of experienced workers are more valuable and harder to be replaced by modern technologies. Human workers can more easily adapt to new environments and tasks than robots. Robotics expert P1T, states *"I don't need to reinvent a human being in order to achieve the sort of tasks that we're trying to achieve".* The robot expert sees that for a multi-step process a single human worker can do all the tasks whereas it might require different types of robots to complete the whole process as robots still do not have the physical and mental dexterity to solve problems the same way humans can. As industry focuses on recruiting new talents, it is equally important to consider the value of the non-transferrable skills of the current workforce before introducing new technologies to do similar tasks.

3.3.2.3 *The Grey Area: Costs vs Benefits*

As discussed above, DMTs and Cobot adoption is considered as an alternative option to tackle labour shortage. The adoption decision will also rely on the analysis on the benefit of the implementation of technology against cost. One of the cost factors already covered as part of employment paradox is the increase in labour cost for skilled labour to work with robots. Consequently, maintaining and attracting skilled labour is also part of the investment in adopting Cobots. On the other hand, the key argument for Cobot adoption is safety, though safety is viewed differently by experts. Based on the data presented, we argue that Cobot adoption based on cost versus benefit is a grey area. First, the consideration of safety is viewed from two distinct perspectives: increased safety of workers by using cobot to replace repetitive tasks and choosing automation over human-robot collaboration. Second, perceived benefits of Cobots against the cost of investment is difficult to quantify. Third, it will boil down to money and the business model.

As Cobots do not require barrier, it decreases health risk by reducing risk around robotics maintenance and taking on tasks that are not ergonomically appropriate for human workers. This is highlighted by the manufacturing quality expert P2M,

> *"the benefits are one which is economic benefits, and the second thing is that we will be able to design more lean processes, when we can have the facility to put Cobots together with human beings. When we see an opportunity to improve our efficiency and where we see an opportunity to reduce the risk on the human operator's ergonomics when they need to move parts. Although it's not too much weight, I mean 10 kilos, but they move in every for the whole day which at the end it is a lot of weight that you are moving at the end of the year."*
>
> — P2M, Quality Director

In contrary, some of our interviewed experts observe that Cobots will challenge health and safety protocols and that in many cases firms are likely to uptake full automation as opposed to human-robot collaboration as the law and connected autonomous vehicles expert P11L argues,

> *"Getting in technology, which is designed to work with humans, because of the safety profile, commercial profile and everything around it could actually cost more than simply just replacing the human. There's very little hesitation about automating something completely and then just excluding the human. From that perspective, all those things line up very easily. You get commercials case lining up very well with the safety case and the legal case because it's also legally easier to demonstrate your safe system of work by having separation. Cobots represent the kind of grey area, when of humans working in the same place as machinery. And to be able to demonstrate the same levels of assurance that it is safe, cost effective, efficient are possible I think*

> *that's yet to be demonstrated for higher complexity tasks especially when there are multiple points of handover from human to machine."*
>
> — P11L, Director of Law and Connected Autonomous Vehicles

Safety is a complicated subject even though Cobots may be beneficial for shopfloor workers, but it will also depend on the health and safety protocol of the organisations and the cost of implementing new protocols to support human-robot collaboration. Whilst safety is the benefit for the implementation of Cobot(s), proving efficiency worthy of investment is still a question at stake as the perceived benefits like safety will still need to be compared against costs. As the quality expert P2M advises for the need to *"make calculation to be sure that we are not making process expensive than it could be. We need to balance what is the cost of the machines and what the cost we are having without the robots."* P2M expands on this analysis that it will need to include the quality of product produced by Cobots as well as the new metrics for quality control *"what is the quality requirement we need for these collaborative robots and how will we assure the quality of the product we manufacture based on the use of cobot and how we can improve our processes taking into account the advantage we have with this automatic system for robot."*

Conducting a cost benefit analysis specifically on cobot contribution can be difficult as it is not as straightforward, therefore, the realisation of benefits versus costs of investments is difficult. Cobots can help improve different elements of manufacturing line though the improvement is not easily translated into a clear monetary value directly associated with Cobots. How much cobot improves efficiency, productivity, and safety in the shopfloor? These benefits are added value that may be challenging to calculate into a definite percentage of how much Cobot adoption will improve the process as measuring productivity and efficiency is also debatable (Kopp et al., 2021). It might be that companies will need to take on a big picture approach as opposed to a pinpoint the exact value on cobot contributions to production line. Technology adoption consultant P9C thinks that if firms want to minimize operational cost, they may only consider spending more money if such investment will come with many good reasons i.e., lower overall cost. The manufacturing expert P2M suggests that in quantifying the level of efficiency, it is possible to measure the speed of the process and how much time is minimized at the bottleneck of the line when Cobots are in used. Though, the measuring of cobot efficiency will depend on the organisations and the challenging question will be providing the benefits of Cobots against cost of investment whether that be from the perceived benefits or safety or the hard numbers of increased productivity and efficiency.

Lastly, adoption of new technology like Cobots will depends on the compatibility of it to the business model and this decision must be made on a case-by-case basis. Although the law and connected autonomous vehicles expert P11L sees that Cobots will pose a legal challenge from safety perspective, this aspect might not be the most concerning challenge for technology adoption and rather the key barrier will be the unique business strategy of the organization. As the technology lawyer states,

> *"for businesses, it's understanding how robotics integrate within their current business model or within the revised business models and understanding what it is that you want to achieve from introducing robotics and collaborative robotics...I think that doesn't necessarily create legal problems, but probably drives the change in business models, to how you manage new technologies within your organization."*
>
> — P11L, Director of Law and Connected Autonomous Vehicles]

Experts see that Cobots will be a good investment from safety perspective, although the view towards this bespoken benefit varies. It is likely that companies will choose automation over human-robot collaboration because it is legally easier to demonstrate that a safe system of work is in place when there is a clear separation of workers and robots. This can mean negative implications through job displacement, as manufacturing technology like automatic machines will inevitably decrease numbers of human workers and will only require small number of skilled workers to maintain the machine. This point will also be further discussed in. Consequently, it is a difficult space to calculate the added value of Cobots as the perceived benefits will need to be compared against the manufacturing process cost. So even if safety is viewed as the key benefit, it is not straightforward in making the case and certainly is not the sole reason to adopt Cobots.

3.3.2.4 *Misunderstanding of the Technology and False Expectations*

The adoption and acceptance of Cobots are influenced by their benefits as well as by the media and the popular culture. We have discussed the perceived benefits against costs, however, there is another side to this conversation. Our experts argued found that external factors can also contribute to employees' fear and lack of acceptance of new technologies. Several of the interviewed experts feel that there is a misunderstanding of what emerging technology can do because if technology has not been properly communicated to the users, it can lead to an unrealistic fear. People will adopt the technology based on the perceived benefits though that that added values might be inflated. Several of the experts felt that there is a misunderstanding of what technology can do and our expectations for it and part of the issue is the technology is not being properly communicate to the users leading to different types of expectations on 'performance' of technology by different stakeholders. Chief technologist P3T gives an example of the current status of AI at time we spoke and the problem of the overselling of technology which builds toward the hype of AI,

> *Because there's a lot of money floating around in the AI market, there's a lot of these making a lot of promises.* ***What I know about AI and the state of technology, we are decades away from meeting what some people will promise****. There is no magic in AI beyond mathematical correlations and*

> *statistics. And unfortunately, that's the only way we're able to implement the technology because the decision making that based on empirical evidence is something that we tried to do in AI and that led to the AI winter[2] because it was just too complicated. And it's only when people gave up on so called symbolic AI and started implementing statistical AI that we started to see the boom over the last decade but that comes with a massive risk which is that these decisions are less accurate but you can make them faster and more cheaply. Some elements of machine learning are based on how the human brain works but that doesn't mean that these machine learning models are the same as brains. How often have you heard about Google or IBM getting some AI to play Go or even do it better? They're nearly always using supervised learning. They work with a highly constrained domain space where there's only a limited number of moves you can make and zero external actors other than the other player. In the real world, goals are often quite vague and ill-defined, you're working with an environment where many different things can change.* ***It's easy to get impressed with the development of AI in these really narrow use spaces. Once you try and scale them, they don't work****. Alexa doesn't work by trying to impersonate a human. In fact, the backend is its 10,000 small machine learning models. And what they're doing is looking for keywords. And there's some machine learning in there you can vary the pronouns and you can add some adjectives in and it will still work but it's quite dumb."*
>
> — P3T, Chief Technologist Officer

This can be problematic for the adoption of this technology. Organizations may not be fully aware of the potential risks and gaps in decision making of the technology which may lead to over-trusting of

2 An AI winter is a period of reduced funding and interest in artificial intelligence research, brought on by pessimism in the AI community and followed by pessimism in the press. See (Umbrello, 2021)

automated decision-making (see also (Aroyo et al., 2021; A. R. Wagner et al., 2018; Flechais et al., 2005). Consequently, the lack of adequate communication on the technology functions can lead to risk in the adoption. Although Cobots bring certain advantages by freeing human workers to work on other tasks, if the technology is not being properly communicated it can be very dangerous. We are already seeing this in the case of autonomous vehicles as P11L stated,

> *"We are, of course starting to see issues where there are accidents, whether one the emerging issues appears to be a fundamental misunderstanding of the technology. A couple years ago, there was the first prosecution in the UK of someone driving a Tesla or rather not driving a Tesla because he was sitting in the passenger seat expecting his Tesla to drive itself in England and he was prosecuted and convicted. You were seeing the risks manifesting itself across the entire board, things being manufactured where the limits are not clear or not understood, things being manufactured where the limits are understood but not communicated properly to humans, and things which are being manufactured which are placing expectations on humans, which they cannot actually satisfy."*
>
> — P3T, Chief Technologist Officer

Besides dangers and risks that may come with the lack of understanding of the technology, it can lead to over scrutiny of the technology. There is a big gap of what the machine can do versus our expectations for machines which is when machine makes mistake, sometime less severe than humans, it becomes a huge issue. This is a challenge that developers face as well as organizations in dealing with the blames and the decisions that Cobots would take. Certainly, the high expectation of the technology will likely influence how organisations implement and use Cobots in particularly to avoid the blame of damage caused by the Cobots. This challenge echoes the concern previously pointed out regarding the adoption of full automation over

Cobots to mitigate the high risks of human-robot collaboration. As technology adoption consultant P9C states,

> *"There's a quite a mismatch between what we expect the machines to be able to do. So, effectively, there're tiny numbers of possible things that were we would forgive a machine for not being able to do but there's a huge number of things we'd forgive humans for. After weeks of road testing of driving lessons, you pass the test, good to go. And then it's all on you. Whereas, in the automated vehicle space, it's likely to be completely the opposite way. That is, it will need years of testing and tons of software testing and all this kind of stuff. And even then, when it goes wrong, we [developer] will be to blame. So, the trolley problem, you can divert the trolley to other tram to kill a bunch of nuns or kill a bunch of kids. But you've got to make a choice. That standard thing is often brought to the fore, because somebody has to program the machine to do that."*
>
> — P9C, Technology Adoption Consultant

In addition, the misunderstanding of Cobots contributes to the over-expectation of robots as they are often being compared to humans. The human-like perception towards Cobots can be dangerous as people may not understand how robots work and thereby it can result in a misconception of robots. As robot ethics expert P5R describes,

> *"People expect the robot to be too human-like and interact with the robot as a human. We were talking about our robot's black box, having a camera and being able to record information, but that is not being the same thing as a robot seeing because that seeing is a very human thing - goes through our eyes up to our brain and comes out and so on. And that's not what a robot does. When a robot processes visuals is all about pattern recognition and that's like a very different approach. This is a very sophisticated processing, you can do lots of things, but it is not*

the human process of seeing. When a robot making a decision, it is not making a decision in the way that a human makes a decision. It's very easy for us to just kind of slip into this kind of humanizing the robots and there's a danger that if you build on those assumptions in the way that you interact with the robot, it will come to situations where just the interaction will break down and you get 'I can't understand why the robots doing it this way'."

— P5R, Robot Ethics Senior Researcher

Consequently, media has the power to influence people's perception towards robotics. There is an issue of overselling the technology and its capability and a lack of communication on the correct information of robots. The promotion of products or applications can be unintentionally misleading, thereby raising false expectations of those users with limited knowledge or experience. Proper communication is needed so that people will not buy into false promises or develop irrational fears. A proper communication is required so people will not buy into their fear and false information based on the misconception of robots especially of what the media puts out. This discussion is captured by a senior lawyer P12L and robot ethics expert P5R mentioned,

"I think a lot of people's perception will depend on what's put out in the media over the next however many years. There're just so many external influences. People will be, as we all are, be influenced by what they read and what they see. So I think when we're talking about robots, there's a degree of element where education is going to be needed to encounter or counterbalance what people who might already have created this impression of the role of robots."

— P12L, Senior technology and data protection lawyer

"Whenever I talk to people about what I do, the first one they always bring up is robots taking over people's jobs, and that

> *they're very fearful of that. And that's the one that gets reported in the press a lot so you get these heightened fears around it. The key one for anybody working in this area is how likely that automation will remove the need for humans or main roles for humans. I think that's kind of one of the key issues and how you address that to a fearful public."*
>
> — P5R, Robot Ethics Senior Researcher

Following the misunderstanding and misconception of Cobots that may lead to the over expectation of this technology, experts discuss different approaches to address this challenge to support the adoption and acceptance of Cobots. Education is one of the key approaches, in particular, the ethics of technology adoption and the need for this to be part of school curriculum. It is important that this discussion starts early, as P10C puts,

> *"What sort of world do we want to live in? If in 2040 we want to live in this world. What needs to be true now? What do we need to be focusing on now to make that happen? For me, academic is nearly there, but it's also about schools. We should be talking more about our society and how we live together and what expectations we have of each other going forward so that we know that there's a cost and the benefit, we know there's a trade off. We need to know more about the human impact of this technology."*
>
> — P10C, Technology implementation consultant

Currently, the consideration on the risks and impact of autonomous systems like AI and robot have not been considered enough because the risks might not be as apparent yet in comparison to other industries. Apart from an educational approach, there might need to a grace period where innovation is required more development time before the technology is made available to the public to ensure that the risks are accounted for. P6C gives an example of energy sector,

> *"The nuclear industry has huge harm potential. But that was recognized early on, therefore, very serious mitigation, regulatory requirements, standards, safety, everything was put up there as soon as it was realized. So in other words, stop development until you can contain it. Nobody's willing to do that with AI because it's still 'nah, we're okay.' With nuclear, it was really obvious what could happen if it goes wrong."*
>
> — P6C, Technology Ethics Consultant

All in all, clear communication of expectations on new technology is required to maintain the sustainability of new technology adoption and avoid misunderstanding. As the misunderstanding of technology influences peoples' perceptions on robots, this has a direct impact on the adoption aspect of Cobots. Therefore, an adequate level of communication should be done throughout from the technology design to the adoption to the end users. Furthermore, designers need to be realistic about what the users or human operators can do when interacting with the robot. They also need to ensure that the firms understand what the technology can actually do and what it cannot do as the information has to correctly liaised to the operators, so robot operators fully understand their roles in the collaboration. This is also in line with the EU proposed (European Commission, 2021) Article 13(2) where the high-risk AI systems[3] *"shall be accompanied by instructions for use in an appropriate digital format or otherwise that include concise, complete, correct and clear information that is relevant, accessible and comprehensible to users."*

Consequently, the important discussion is how do we design (see Section 3.3.9.3) a robot in a way that helps people understand a robot's capability? It may be argued that education alone is not enough and thereby there is a need to consider how design can be play role in helping to correct peoples' impression, perception, and understanding of this technology. At the end it is very important to ensure that we communicate clearly with people of what can the technology do

3 See Section 4.2.2.1 for the discussion on Cobots as high-risk AI system

and cannot do, this will help ease the fear of robot taking over so people see how they can use technology for their advantages. We need to show that technology is a 'smart tool' but it does not replace humans and it does not perform the way humans do.

3.3.2.5 *The Acceptance Factors of Cobots*

To accomplish employee acceptance of new technologies, it is imperative to include as many different stakeholders in the decision-making as possible, as well as ensuring that the benefit of technology is communicated properly. In addition to offering employees direct input in the decision-making, it is key to take them along the process of implementation in other ways to help them accept new digital manufacturing technologies in their workplace. For instance, people are more likely to accept new technology when they are given the information they need about the transition as well as the reassurance that their jobs will not be negatively impacted. P12L remarks,

> *"If people don't understand the benefits that technology can deliver, they're unlikely to run to adopt it [. . .] Whenever you're talking about robotics, or AI you have to take people along on the journey. Obviously, most people have to understand what it is and what the impact is. No one will question it if it's working. But if it's not, people are going to have lots of questions and to be able to explain that to everyday users is going to be a really important part of creating an acceptance."*
>
> — P12L, Senior technology and data protection lawyer

This is also noted by P14M, *"Taking them on the journey. You just don't choose morning and it's there overnight. It tends to scare people when you turn up and there's a new machine there."* P2M confirms the importance of informing their workers and maintaining their morale by illustrating how their company implemented new technology into the manufacturing line and managed to reassure employees that the introduction of new technology would not replace them, *"We always have the plan of what to do, why we want to do that kind of change in the* *process, how they will be impacted, and how we have to reorganise the activity. I will say in our activity, we have no issue with that. In fact, nobody has gotten fired. And this is why it's easy for us just to explain what we want to do and what are the reasons such as our company will be more profitable so they are not afraid that they will be fired."*

According to our survey, 78% of shop floor respondents and 70% of managerial role respondents agreed that the long-term objectives of the new technology were explained in detail to the workforce. In addition, we also asked participants whether they have any input in the decision-making on new digital manufacturing technologies. We found that influence on the decisions does not only take place at management levels, but also at other levels within the company and that employees in different roles felt in varying degrees that they had a say in the acquisition of new systems. Although only 10% of the operators and 9.1% of the quality inspectors confirm that they have 'a great deal' or 'moderate amount' of input, a much larger percentage of the engineers (40%) say they have influence. However, the maintenance technicians and production technicians do not play a role in technology acquisition decisions at all. Managerial employees indicate different levels of decision-making: from middle managers (23.9%), HR, admin, and finance role respondents (30.8%), to production and senior managers (41.7% and 77.8%, respectively), and finally CEOs (100%).

Some of the experts, including manufacturing experts, are aware that inclusion in decision-making is key and indicate that such practices are already adopted in their firms to ensure employee acceptance. Other experts feel that there are not enough organisations who represent workers and that impacts of new technology implementation are not being fully assessed. One of the lawyers, P7L, stated that there are consumer protection organisations that speak for the user of the product, but that there is not enough labour representation in the workplace: "We have seen a massive drive to delegitimize and disempower union movement and at the moment it seems to be as trivialities rather than the big issues. But in principle, I think there needs to be a massive pro-organised labour and all of that." P10C shares a similar view,

> *I suppose the representation needs to be from the point of maximum impact wherever that falls in our society. If you're in Germany, you have workers' councils and trade unions and to understand the impact of robotics, they'll need to, without being Luddites, understand that technology will change the customer demand and will put the firm that you work for out of business if you don't adapt in some way. So, we have to have the impacted represented. You can name all the usual stakeholders, the institutions, the government, but I'd really like some sort of independent arbiter, someone who can bring about all those softer issues that we've talked about."*
>
> — P10C, Technology implementation consultant

Our survey is in accordance with the experts' view that there is a low level of labour representation. It shows that only 24% of the organisations where DMTs were introduced had trade union involvement in the acquisition of the new technology. Besides having input into the technology acquisition, it is important for workers to have a continued dialogue with the technology designers and producers because involvement in the technology implementation process can lower their resistance. The survey results show that participants indicate they were able to express their needs and requirements to the technology producers extremely or very well in 48.6% of the cases, whereas 25.1% said that they either expressed their needs slightly well, or not well at all. Looking at the respondent's involvement with the producers during the integration of the new technology, we separated it into three stages: (i) the design/development stage, (ii) the installation/start-up phase, and (iii) the normal operation phase. Participants' involvement is highest in the third phase (see Table 3.5).

	DESIGN/ DEVELOPMENT STAGE	INSTALLATION /START-UP PHASE	NORMAL OPERATION PHASE
A lot	20.2	24.6	26.2
A moderate amount	15.3	21.3	27.3
A little	64.5	54.1	46.4

Table 3.5: The three stages and degrees of respondents' involvement with the producers during the integration of the new technology

3.3.3 *Theme 2: Regulatory Challenges*

Does the law stifle innovation? This question always creates a contentious debate on the role of law in technology adoption and vice versa. It is expected that the law will face challenges in regulating transformative technologies such as Cobots given the criticisms that a regulatory gap arises from law being far behind technological advances (Brownsword et al., 2017). In addressing the criticism that the law is unable to keep up with technology, experts view that the law is also evolving, and it will not always play catch up with technology. Certainly, the current concerns focus on question surrounding the suitability of the current framework to govern the implementation of emerging technologies and Cobots. To investigate whether the law is the key barrier to adoption, there is a need for more scrutiny on this perception. Furthermore, safety was brought up quite frequently as legal issues although we found in this study that the concern of cobot safety is not only a legal concern, but this aspect needs to be discussed and explored in respective to Section 3.3.7 as well. One of the key objectives of this PhD thesis is to understand the legal challenges and implication posed by Cobots from the perspective of industry experts.

In this section, we found that the legal challenges range from the complexity in applying the current legal system to Cobots to designing future regulatory system to support Cobot adoption.

3.3.3.1 *The Infamous Debate of Law and Technology*

The interesting point to begin with is the two contradicting viewpoints of the relationship between law and technology. Is the law always behind technology? We found that the approach to answer this question was likely and potentially be influenced by the culture and professional background of the experts. We recognised further exploration on the fundamental concept and the nature of the legal system is required, however, that will be discussed in Chapter 4. When engaging with this debate, it should be made aware that there needs to be more considerations of how the law is behind and how it delays innovation because innovation cycle ranges from being developed to being adopted. Consequently, we observed that the conversation could signify that there might some misunderstanding including the limited knowledge of the 'law' when examining its applicability to the emerging technology. This particular observation does not propose a new debate on the gap of knowledge between technology and legal experts in relation to the regulation of emerging technology. Given the premise of this PhD thesis, it is not our intention to substantiate this debate as this is a mere observation based on our data analysis that seems to reflect the on-going debate of differences in the technology and law communities. Furthermore, the findings show quite an interesting discussion on how these differences play out in the real world as the experts have influence over the decision-making process and without clear communication about the law they could have created and started a false claim of the law being the barrier to adoption. The notion that the law is behind and preventing the adoption could be due to lack of understanding of the law, making this debate one of the key challenges to Cobot adoption.

The main criticism towards the law being behind technology centrals around the lack of evidence on how Cobots will be used and the risks of it. Experts with technology background view that the law relies heavily on previous case law to set precedent on what can be done and therefore the introduction of emerging technology is challenging for the law to cope with. As P15M and P9C stated,

> *"I think the regulators are way behind where technology is. And the reality of that is actually what is causing us problems because going back to the unknowns and the Cobots and how things work. There is no case law. There's nothing stated, there's so much of it that sitting in common sense and would I be prepared to risk doing that? Rather than 'I can go to this and I know that there has been experience of this and would that fit in my business? Therefore, it's not a risk if it fits in my business. Or no, it wouldn't, so I better not do that.' So I think when the regulators invariably catch up, by that point, if you're interested in what we're doing now, it's too late. Or it's very much 'me too'."*
>
> — P15M, Robotics and Automation Expert

> *P9C, "In general, technologies are doing new things that have not been done before. They're using things in ways in which they haven't been used before. And I think the law really struggles to keep up, honestly, mostly because the law is based on all that stuff that's in the past."*
>
> — P9C, Technology Adoption Consultant

However, this criticism is not shared by legal experts. In fact, the law is adaptive and fast to respond to innovation. Perhaps, the law is being used as an excuse for the slow progression of technology, as highlighted by technology law expert P13L,

> *"so the claim that technology always outpaces law is under theorized and inadequately evidenced because it doesn't acknowledge the way in which law has the ability to quickly adapt when*

it needs to so and also that there's a very big difference between a rule which is concrete and specific and a standard like unauthorized access to a protected computer which can evolve with technology over time. To the extent people are saying, 'gosh, we don't have driverless cars because of the law,' that should be much more heavily interrogated. It looks to me the reason we don't have driverless cars has to do with the imperfection of driverless cars. And so therefore, when you can have the cases that the technology can't address, it seems to me just as fair to blame the technology as it is to blame the law... So there's been a much shorter time between someone having an idea about what to do with robotics, and there being a law and policy response. So one of the interesting things about robot law has been that state lawmakers are more attuned to the idea that there will be some robotics breakthrough. And so they have been very quick to get in there. Over the 10 years that I've been studying robot law, ironically, some of the big breakthroughs in robotics or some of the ways in which robots would be normalized, haven't happened, but the legal ecosystem has become more adaptive. And that kind of interesting because it runs in the face of the usual story we hear that technology is moving so fast. I don't think that's proven true in the 10 years I've been doing this. This narrative exists is because it is corroborated by industry and by technologists who use the law as a scapegoat. They can't build robots that work that anybody wants to buy and then they say, 'you know what it is? It's these damn laws.' So the law becomes a scapegoat for technologists who can't get the product to work."

— P13L, Technology Law Professor

Following this argument, the important aspect to consider is the development of technology also takes time to design, develop, and commercialise though ironically there is also a discussion on how many innovations can quickly become outdated. Whereas the law is not perfect but its implication on technology lasts for a long period of time and in a similar manner to technology it will also need to be updated to keep pace with the evolving technology landscape. As P13L explains,

> *"Technology actually takes a long time. And law takes some time too but not any more time than technology and technology hits some really hard limits sometimes, in a way that law does not. There's no Moore's law for law. The Computer Fraud and Abuse Act, people are arguing that 'it is outdated, it's been around since the 80s, it's not suited.' But remember that the CFAA worked reasonably well for a long time. We've had these laws on the books for an extremely long period of time, maybe they're imperfect, but their imperfection is not an argument that technology is always outpacing law. Their imperfection is that maybe law is not always great, not always perfect, which is well understood by anybody who studies law that laws can be over and under inclusive. The breakdown of policies that have been on the books for 20 or 30 years, along specific lines, just suggests to me that over time, with any kind of law, you need to update it because of changing conditions on the ground. But it does not suggest to me that robots are always outpacing the law."*
>
> — P13L, Technology Law Professor

To approach the future of technology regulation, current case law needs to be taken into consideration as well as the outlook of technology. Paradoxically, law and technology are very similar in a way that they evolve. As technology moves forward, regulators need to innovate on how to approach the governance of emerging technologies. In field of human-computer interaction, future studies and design fiction are commonly used to facilitate creativity for the future of technology design and its place in the world (Ballard and Calo, 2019). These methods allow designers to depict the future we want to live in and envisage the scenario where the technology would be use and for what purpose and thereby, they can gain a better insight into design and development of the product. The law was not known to be innovative (Ganesh et al., 2022), however, as technology has evolved, the need to consider the implications of technology to the future is required. This is highlighted by P8L in the case of regulating autonomous vehicles and AI,

> *"Generally the law is looking backwards, but what the Law Commission is looking at is what is working and not currently working, this is different. It is designing a study for model for the future. This is the forward looking exercise... Because previously the idea was that all you just needed was rules and keep the rules up to date and the rules specify every variable. You cannot prescribe and keep prescribing every component so what you do is design the legal and regulatory system which has general duties supplemented by specific duties. Let us assume 2 different AI applications. 1 is equipped with razor sharp blades and slicing meat in a repertoire and its projecting blades which are chopping meat at very high velocity. Second AI machine, its soul function is to decide what fur to use on a soft toy. Your use case regulation of those 2 machines should be driven by risk. There maybe common elements to how you can configure it in term of those AI machines having certain amount of voltage or frequency of but the thing that they are doing is fundamentally different use case"*
>
> — P8L, Senior Lawyer (Partner)

To summarise, the statement that the law is behind technology cannot be taken lightly as it comes with many facets as highlighted in this section. The law by nature is not behind technology and the consideration should be on the approach taken by those who draft the legislation and the challenge to balance the needs to be proactive and inclusive but neither too specific nor too vague. The debate mirrors children literature of Goldilocks' dilemma in trying different approaches to find the most suitable and well balanced.

3.3.3.2 *The Chicken or the Egg Paradox: Law or Technology First?*

Following the narrative above, there are certainly rooms to improve whether that be bridging the knowledge gap or create a better understanding of law and technology relationship. So how do we solve this problem of the regulatory gap? First, we need to understand the contradicting viewpoints on 'the fundamental of the law' from the practical point of view in term of the current circumstances with regulating technology. As Cobots are still relatively new to the industry, experts see that there is a lack of regulatory framework and guidelines which results in hesitations to adopt the technology despite the readiness of the collaborative nature of the technology. Therefore, Cobots are not being used to its full potential and still have to be kept behind a barrier due to safety concern as P15M shined the light on this issue,

> *"We bought universal robots because they are collaborative robots and we know they can be collaborative. We did some initial design with it. And then when we reviewed it, because of the fact that there was no legislation, we weren't quite comfortable with it. From a business point of view because there was nothing we could hang our hat, so at this moment, cage it. So, the view is that we've got the collaborative. The other thing from health and safety point of view, because it's such a new technology, our head of health and safety said there wasn't enough legislation around it, there wasn't enough case law, there wasn't enough experience."*
>
> — P8L, Senior Lawyer (Partner)

Innovation expert and technology lawyer share similar viewpoint to P15M, as P14M stated "No one wants to be the first person to move in the area because the risk with being first but that's our challenge." P12L recognises that "identifying and plugging the gaps would be useful for creating certainty in the market." Because start to see a pattern of the chicken or the egg paradox when reviewing the opinions on technology adoption and the law highlighted by experts. On one hand, it has been proven fruitful to let innovation runs its course with the hands-off policy in order to incentivise technology development (Ganesh et al., 2022). On other hand, the lack of regulation alarms the adoption of the technology due to the lack of uncertainties in legal proceeding of 'what if something goes wrong' with Cobots. As there is not enough technology available in the market, therefore, experts view that regulators and policy makers are likely to avoid intervening until more Cobot adoption is realised. Hence, it is important to emphasise on this paradox that the market, from the adopter's perspective, needs and wants clarification from legal perspective in dealing with Cobot adoption.

In supporting of the statement above in that law plays a crucial role in technology adoption, experts believe that law does not hinder innovation but can help promote 'better' innovation. The Study presents a unique insight as law and innovation have a very complex relationship and often that we observe the criticism that law is too rigid and not keeping with innovation and thus advocating for less regulation. In working with technology, P12L stated *"the law should be an enabler. And what we're trying to do is find ways of the law keeping pace with technology. So it's never the thing that's holding it back."* Accordingly, P13L shared that the law is needed for a better and safer innovation,

> *"when you don't actually put any guardrails on things and just believe that hype, You get Facebook. As society, you're like, 'well, it's just bits, not bones. It's just pieces of information, how bad could it really, how bad could the harm be? Let's completely take our hands off of this because the harms are not physical in nature, people are not getting hurt physically. And what happens? You get this behemoth that is causing harm everywhere. So when you buy into that narrative about law interfering with innovation, you run into the situation."*
>
> — P13L, Technology Law Professor

In the recent years, social media outlets face criticisms on the safety and privacy of the users from the perspective of data protection regulation. Global Technology corporation like Meta, owner of Facebook, is an example of data-driven platform and the data protection risks it presents where users are not fully informed of the collection and use of the information as seen in Facebook Ireland and others v Gegevensbeschermingsautoriteit (C-645/19, 2021). As the impact of social media has not been immediately recognised, experts see that this case study should be a lesson learned and certainly applicable to cobot regulation. P6C also echoes P13L's perspective that the law should ensure that the product is safe before becoming publicly available which implies that the time of the process from research and development (R&D) stage to product reaching consumers will be longer, but it does not mean the rate of innovation will hit a brick wall, as P6C states,

> *"Of course, it going to slow it down without question, but it's a cost benefit. So it becomes a judgment of the values of society. Are you willing to let people die or are you going to let these people get rich? It's as basic as that. Innovation does not have to be slowed down. Because what ends up happening is that there's a rush to the gate, and everybody pushes through whether they've got anything of value or not, and that's unsustainable. So the public is the victim in terms of having the test out of these products. There will be less innovation and there'll be fewer products to market, but those products that do make it to market will be safer and more secure and people will be happier with them."*
>
> — P6C,Technology Ethics Consultant

In addition, failing to maintain legal obligation will result in financial ramification which enforces technology providers to carefully operate in compliance with the law as P12L mentioned, *"what we're seeing from the manufacturers is that because of the level of fines for really serious breaches of GDPR, they are often asked by their senior stakeholders* *as to what they're doing in order to ensure that the product that has been developed is compliant with data protection legislation."* Therefore, Legal intervention is needed before technology will be adopted and if there is not enough out there in the market to be regulated then this actually presents a prime opportunity to shape how Cobots will be adopted. This allows for the law to put down more proactive measures as opposed to ex poste solutions. The debate might play out differently if we view it from the perspective of technology providers, however, the focus on this thesis is on the adoption perspective; thus, it is clear that organisations want to clarity and certainty when adoption technology and the law might just be one of the instruments to provide that level of assurance for Cobot adoption.

3.3.3.3 *The Utopia Vision: Harmonising Regulatory Instruments*

Accordingly, moving forward with regulation, experts see that there is a need for harmonizing the regulatory landscape of Cobots. As discussed above, regulation is needed for Cobot adoption but currently there are still uncertainties with the legislations. Having appropriate regulatory frameworks for Cobots are crucial for cobot adopter in dealing with risks and the robots' users i.e., employees. In addressing the regulatory gaps, harmonizing regulatory instruments is required; though vision is recognized that it is a utopia approach, but experts still see the attempt as a step forward to bridging the regulatory gaps but there are many challenges that need be addressed for this vision to progress as technology lawyers P8L and P12L explain,

> *P8L "The UK law commission, the standards that are set to be what we want to achieve for robotics whether it is vehicles or manufacture, really need to be global standards for safety and assurance because we are in the interconnected world" if the AI is regulating what power is going through the interconnector, then we need some form of consensus and the transnational development of standards. The standards that we want to achieve need to be done but it is difficult. The common view as to how*

civil and criminal react to autonomous and AI technologies and robotics, we have not gotten any form of International legal system that is going to do that."

— P8L, Senior Lawyer (Partner)

"I talk about data protection legislation I typically talking about GDPR. So the legislation that applies in the EU. But some of these products will be on a global scale. And so how do you I think one of the questions probably for vendors is how do you ensure compliance with data protection legislation for example, on a worldwide basis, what approach do you take? Do you develop different products for different markets, which is time consuming and costly? Or do you do your due diligence in advance and create a product which meets the higher thresholds which essentially is expensive. Or do you take a risk based approach? And if you take a risk based approach, what level are you assessing your risk at in terms of your ability to comply with laws in certain countries?"

— P12L, Senior Technology and Data Protection Lawyer

Consequently, another challenge to harmonizing the regulations across the board is due to various legal regimes for 'safety', which is a particular issue in relation to the collaboration between human and robot can make it hard to regulate as it is highlighted by P11L,

"The regulation of safety comes from multiple angles, there is the product safety regime, which is the thing itself needs to be safe, then a way that it works becomes part of your safe system of work, which is then managed by a different regime. And those duties are deliberately broad. Present that you've got multiple points of engagement and disengagement of the human machine interface. And it's dynamic. For example, if you're driving a car, an automated mode, something can fall into the road or it can start snowing immediately, extraneous circumstances will mean that the task needs to be done somewhat flexibly. There has

> *to be some flexibility and adaptability of the old fleet, the system that exists between the human and the product, it's no longer an assembly line. So the human and machine interface have to be constantly fluid, constantly dynamic. The rules that have to be in place will be more like a framework and less of a fixed system where the machine stops, and there's a clear indication of side lights go off and all the rest of it stops whilst human then come and do whatever that be. It was quite difficult to imagine how that [non-fixed system] could be regulated."*
>
> — P11L, Director of Law and Connected Autonomous Vehicles

The collaboration aspect makes it difficult to regulate Cobots considering the safety control and liability angles. To overcome this, it is suggested that where proving liability will be difficult unless the robot retains as much data for as long as possible. However, this can get messy with data protection regulations in particular data minimization principle although it might be necessary from commercial perspective. Companies will want to have proof especially when there is more than one stakeholder involvement, P12L points out,

> *"it's understanding who has responsibility when something is in autonomous mode. I think it's also going to be about the commercial arrangements that sit behind that because working from an assumption that if you have something that's operating in autonomous mode, it's unlikely that you're just going to have one stakeholder involved in that. So you're talking about people who have provided and developed software versus people providing the hardware, people providing the data, if something is operating in an autonomous mode, and something goes wrong, how do you attribute fault, for example?"*
>
> — P12L, Senior technology and data protection lawyer

Consequently, we discussed earlier in term of the suitability of current regulations for Cobots. Although, the law by nature is not behind technology, it is evolving with technology and in the meantime, we must work with the current legislations. Applying the current legal frameworks to human-robot collaboration can be difficult in particular when determining the level of risks and the lack of definition in such context, as P8L explains,

> *"House and safety law is a very clever law; it was designed in the early 1970s. It has a very good principle which is those who introduce the risk must control the risk and show that it is managed to a level of as low as reasonably practical. The difficulty is that nobody has defined what is reasonably practical."*
>
> — P8L, Partner (Law firm)

The complication stems from the multiple parties involve in human robot collaboration and determining the level of mitigation that is 'reasonably practical' can be therefore subjective. This interpretation is unpacked further in Chapter 4. To harmonise the regulation of Cobots, there are several pain points to overcome but it is the vision that share by different stakeholders. Working towards this objective will be a long road and require future studies to help support experts in approaching the outcome that balance the benefits of Cobot adoption as well as society.

3.3.3.4 *Cobot Law: Challenges and the Future of Robot Law*

When looking at the route forward for Cobot regulation, one of the aspects that came up in the Study is the conversation around what should the future of the law look like to regulate this type of technology? We have identified lack of regulatory framework could be due to 1) the law could be too specific and focus on one type of product 2) human-robot interaction makes it difficult to determine future framework for liability 3) there is not a harmonization in regulation. At present, the legal landscape for autonomous systems and robots appears to be rather scattered, yet sector specific. Drawing upon multiple regulations, should there be an umbrella legal framework for AI and robots? When this Study started, there were many discussions around AI and robot regulations. As the discussion continues, in the EU, there is now a motion on enforcing AI Act (European Commission, 2021) which is closer to a blanket legislation for all autonomous systems, echoing the point technology law expert P12L mentioned when the Study was conducted in 2021,

> *"The start of the question becomes about do we need to have very specific legislation that focuses on these new technologies in the same way that something like GDPR updating for a digital age?.... I think we need to look at, rather than having a patchwork quilt of legislation that only applies to certain aspects depending on what you're doing and which sectors you're operating in, a need to have clearer and more tailored legislation that looks at the use of automated systems robotics. Having kind of potentially more holistic legislation will give people some assurance around technology and a better understanding of where people's responsibility sits. And what happens if something does go wrong. I think probably something that's not too dissimilar from how GDPR is approached— some of the requirements into technical and organizational measures."*
>
> — P12L, Senior Technology and Data Protection Lawyer

This direction toward regulating robots is also discussed in literature where Lewallen (2021) recognises the challenges and difficulties in regulating new technology would be due to the more integration of different sectors. The author highlighted that as one sector adopts a new technology, it will going to change the way business and policy are conducted and will have a ripple effect in other sectors which different governing arrangements and jurisdiction would tie together. Hence, the future of robot regulation cannot be taken with just the current understanding of the technology, but we need to think about the potential of this technology and how it could be used. The legislation needs to be designed with this aspect in mind otherwise we could risk the regulation being too prescriptive which will only result in the law being incompatible with emerging technology which can lead to issues with adoption. For example, San Francisco considered banning delivery robots as it poses potential dangers to pedestrians (Harris, 2017).

This city is a home many giant technology companies as well as incubators and start-ups so the approach to ban the testing of technology appears to be a reactive restriction as opposed to having a proactive solution that allows technology testing but within certain scope given that the assessment of technology and its impact are considered. As P13L highlights,

> *"One of the problems is that the law is moving too fast. And it's actually a problem for innovation. If you take the example of robot delivery, a number of different States decided to pass laws about robot delivery. State legislators are specifically looking at the technology and passed specific law literally say what exactly what the company is doing is okay". So they say, 'if you have a cart and it has six wheels and is only 90 pounds and it only goes on a sidewalk and it does this and delivers this kind of thing then that's okay.' Is that the best way to go about planning for robotic delivery in your state? To take whatever some startup is happening to be doing and enshrining that in the law? No, that's moving way, way too fast and it's speaking way too specifically. But the right thing to do would be to sit there and go, 'okay, so it looks like there are now these robots, and they have enough sensors and enough bandwidth and enough intelligence that they can move things around our cities. well, what are we worried about if it would go wrong? What do we need to clarify?' Not literally what the startup is doing and nothing else is okay."*
>
> — P13L, Technology Law Professor

Furthermore, there needs to be a more extensive regulatory approach when dealing with autonomous systems providing the constant involvement of multiple stakeholders. Experts view that the current legal system and framework are basic and binary systems. The law deals with human faults in determining if a party or person is responsible for the damage in consideration to regulatory standards, a negligence standard, or common sense of objectively reasonable (Atkinson, 2014). As the law firm partner P8L explains the process they adopt as part of providing government consultation to regulating autonomous system as an example,

> *"When you move to a connected or autonomous system or either autonomous vehicle individually or particularly where you have a complex system made up of swarm type of technology interacting with each other that is not a simplistic binary regulation of the conduct of one person. If you were doing a business strategy, what you would do is you would say where do we want to be, where are we now, what's the change in management program to take us from here to there and the change management program would encompass structure, people, culture, operation. The law is no different. We're really focused on is understanding what does the current regulatory framework say about what you can do? And what needs to change in order to enable the adoption of technology? In our work identifying what needs to happen between now and the future scenario enables us as lawyers to come and learn in real time and understand the technology and understand use case scenarios so that we can then apply what we know and our skill set to be able to develop that regulatory picture to identify what needs to change."*
>
> — P8L, Partner (Law firm)

The route forward will be to conduct a gap analysis or a landscape study to identify the current legislations relevant to autonomous systems and the areas that need to be improved. This similar approach is proposed by Fosch-Villaronga and Heldeweg on the iterative regulatory process for robot governance (Fosch-Villaronga and Heldeweg, 2018). Furthermore, when considering the regulatory picture as identified by P8L, the challenge of allocation of liability and obligation to relevant parties from technology designers to those who are using the technology will need to be explored further. As we discussed in Section 3.3.3.3, in a utopia world, the responsibility should be distributed to all parties to ensure the best protection possible. However, autonomous systems pose a complicated arrangement of liability distribution and responsibility gap, as highlighted by P6C and P7L,

> *"Looking at two entities, a biological entity and an entity that's a machine, that machine has so much more capability of harming than that human could. So where should the responsibility be? It's not just on the human. It has to be on the design of the machine, the operations, the maintenance, where it's located, interactions, all of those things, the workflow itself, all should be considered."*
>
> — P6C,Technology Ethics Consultant

> *"So how do we allocate liability if something goes wrong? And there's a high level expert group of the European Commission at the moment looking at liability and AI so the legal system is also very much influx on that. Lots of people are concerned about what they perceive as a responsibility gap. Something goes wrong and we don't know who is to blame. Is it the programmer? Is it a trainer? Is it the human who interacted with it? It all becomes really, really complicated."*
>
> — P7L, Law and Technology Professor

This challenge deals with risk and insurance which are explored further in the following sections. Besides risk and liability challenges, the responsibility could lie on designers in ensuring the safety of Cobots which can be difficult to determine the level of safety considering the role of human in the collaboration with robots. One of the key elements that set Cobots apart from industrial robots are the collaborative nature. This technology is meant to work with humans by operating in anticipation of the unpredictability of human behaviours or the norms. This is a design Section 3.3.9 challenge as well as legal challenge. When looking at regulating Cobots, taking on a prescriptive approach on how Cobots should behave will be challenging as Cobots will need to have certain flexibilities in how they behave to adjust to the unpredictability of human movements. Whereas the law can be very rigid, and it will be difficult to prescribe how Cobots should behave in order to comply with the law can lead to more issues when Cobots are operating in the real world. Though, this is not to say that technology will need to be more 'human like' but there will be elements on how Cobots should behave given their interaction with humans and certain levels of understanding of human behaviors. Now, when robots need to make the call on a very tricky situation, how should it be programmed to make the 'right' decision? When regulating Cobots, to what extent should errors be acceptable considering the limitation and responsibility of the designers to embed 'social norm' in the robots? Social norm is not a written rule so the difficulty to consider is to what extend the law should influence certain level of requirements for robots to function in the real world whilst ensuring that the technology still complies with the existing law as the technology adoption expert P9C explains using autonomous vehicles as an example,

> *"So the machine is deciding what to do and somebody has programmed it somehow to decide what to do. There's a big chain of responsibility if something goes wrong. Whereas in normal vehicles, the chain of responsibility is quite short. It's the driver. And every now and again, there might be a mechanical or a technology thing behind the driver, the brakes failed or something like this. This is the kind of thing where you can trace back but that's certainly one of the biggest challenges in automated vehicles, who was responsible if the machine does something wrong. So another example is it is against the law to park your vehicle on the pavement to walk away. But almost every delivery you got, somebody puts two wheels on the pavement to let others pass. If these automated vehicles are prevented from do-*

> *ing what we normally do as humans, you can imagine that they won't be nearly so successful or easy to work with and have to abide by the letter of the law."*
>
> — P9C, Technology adoption consultant

There was an incident where an autonomous vehicle was pulled over by the police at night as its headlights were not activated. The car stopped upon being pulled over, but it then drove across the intersection and came to another stop with its emergency lights on, leaving the law enforcer to follow the autonomous car in confusion. The autonomous car company claimed that technology worked as intended given that where the car was being pulled over by the law enforcers it was deemed unsafe to park therefore the car moved forward to the nearest safe location to park (Sharp, 2022).This bizarre incident shows the challenge in the design of technology in compliance to the current law while performing in a real world setting which speaks to both regulators and designers in regard to the future of law. Robot regulation is intended for enforcing how the technology should be designed and used but it should also consider how technology will function and perform in the real world with conflicts when humans are not always the perfect example of law in practice.

Thus far, we have already highlighted many challenges in the future of regulating Cobots from the fundamental debate of law and technology, the lack of harmonized regulatory framework, and the liability gap of multiple moving parts. There is not a silver bullet that can addressed all the challenges; however, experts have called to attention the need for collaboration of all parties involved as highlighted by Law and Technology Professor P7L,

> *"First, the usual suspects of government regulation. Second, a big stakeholder is manufacturing industry. To regulate, we need to know from them as well what is actually doable, feasible, what works. There are already organizations that represent some of the other stakeholders like consumer protection organizations that speak for the user of the product, so civics or civil soci-*

> *ety in various of its forms, and I think in the workplace and again from all that I can see this is for my liking not happening enough, labor representation. What's the role of the Union or the work council or the workforce itself? We obviously have seen a massive drive to delegitimize and disempower union movement. And at the moment is it seems to be as trivialities rather than the big issues. But in principle, I think there needs to be a massive pro-organized labor and all of that"*
>
> — P7L, Law and Technology Professor

Currently, experts view that employees are underrepresented in the movement of technology adoption even though the adoption of Cobots will directly impact the workforce. Although the decision of Cobot adoption lies within the business operation as we have discussed in the section above, however the sustainable technology adoption will require employee acceptance. Therefore, they need to be involved in this discussion and how robots should be regulated considering the impact of such technology. Consequently, there needs to be a fair conversation where the benefits of Cobots are being communicated clearly as see in the acceptance factors discussion. The technology consultant 10C that in consideration to stakeholder and communication, we need to ensure that those who will be impacted are represented. As the government is pulling together leaders to discuss the vision of technology adoption, P10C emphasizes that they need to cogitate on *"ways of how do we make use of this technology to make us more productive, to make us safer, but also to protect us from possibly damaging impact on our society of all these people being put out of work immediately? How do we phase in and evolve some of these advancements? The representation needs to be from the point of maximum impact wherever that falls in our society."* The expert recognises that it is not just the impact of the technology adoption that requires attention. As part of the adoption dialogue, a discussion around impact of not adoption technology needs to be considered as well in particular with in the conversation with workers councils and trade unions.

> *"They'll need to, without being luddite, understand that technology will change the customer demand and will put the firm that you work for out of business if you don't adapt in some way." So we have the impacted represented. I think we have to have the people who are in charged. It's a really difficult one. I mean, you can all the usual stakeholders, the institutions, the government, but really I'd really like some sort of independent arbiter, someone who can bring about all those softer issues that we've talked about and not just necessarily people related but environmental related as well. So that we know the cost of what we're doing in the round, not just in the specific."*
>
> — P10C, Technology Implementation Consultant

In consideration to the power of stakeholders in regulating Cobots, the market or industry may come into play as a form of technology regulator. This is not a novel approach as it has been established as part of technology regulatory instruments by Lessig (2009). In the case of which the law cannot strike the balance and answer to the issues with insurance and liability where there are multiple stakeholders involved in developing the product, we may reach the point where market and commercial arrangement will come into play, albeit complex arrangement will be required which will depend on industry's appetite to it, and there will not be a need for specific regulation on Cobots anymore. If the law is still catching up, complex commercial arrangement may be put in place and it may stay that way as P12L puts,

> *"I think we will see iterations of that over the next however long decades that look at potentially if the industry can't do it at regulating how you deal with insurance and potentially some of the issues around liability where you have multiple stakeholders involved in developing products, big robots or complex AI that you use to interface with, kind of in hospitals, for example, where it looked at addressing some of the issues in terms of how you portion liability and responsibility, and how you address that.*

> *But it depends on I think people's appetites to that because I think what you end up creating some quite complex commercial arrangements in the background."*
>
> — P12L, Senior Technology and Data Protection Lawyer

Experts view that the industry leaders can be the key actor in responsible technology adoption, and it could be more efficient than government initiatives given the power to control the market and negotiation through the supply chain. This argument is highlighted by Technology Ethics Consultant P6C,

> *"A self-organizing criticality [is] where you have a snowball effect of one set of big suppliers pushing down to the supply chain those requirements. That's the other and more feasible way that this can actually happen because it has happened historically, and it will happen, but only with the power of those who say "you must not do business with me if you're going to do this way. And that way, one very large [corporation], let's say for example, it would put in all of its contracts, that you now have to be sustainable, ethical, human rights, etc. And that would force that self-organizing criticality down through their supply chains and that's how that would work. So until that happen, until there's a global leader, that is rich enough to be able to say, "I'm going to push my weight around here, do it this way, and I can afford to forego the profit while you sort yourselves out and I reject my supply chain." Until that happens and governments aren't going to do it, we're not really looking at a lot of optimism in our future."*
>
> — P6C, Responsible Technology Consultant

Whether it be the market or the law as regulator, safety and liability will still be a subject to unpack especially the acceptable of risks. We have pointed out the regulatory challenge of Cobots programming in coping with compliance as well as the unpredictability and the imperfect of humans. This point will highly influence on what is the acceptable risks as a senior lawyer P8L raises a concern *"we cannot answer the questions about the autonomous and AI base systems without having an honest question about what is a permissible legal level of not failure or of harm."* Although the law can be binary in dealing with negligence – guilty or not guilty – the evaluation of such evidence will be complicated with autonomous systems as we have highlighted. Therefore, when considering risks, perhaps if it is not possible to set a standard of acceptable level of risks as this could be a case by case basis, it may be that we also need a baseline of permissible level of no harm as a threshold of regulation. Although, this is not a new conclusion, 'do not harm is a well known first rule of robotics. Though the rule is fictional but Asimov's laws[4] are not far off from reality. Because the issue is the calculation of that probability in the context of human-robot collaboration and the unpredictable actions based on the interaction with the human workers. The question is how will this factor be translated into designing law in which takes into account that to certain extent the adaptive nature of human behavior will be replicated by robot as it is learning a new task and therefore resulting in volatile risks? Robotics expert P1T shines the light in this challenge,

> *"In terms of safety if you're designing a safety critical system, what you would do is some kind of analysis of that system where you do basically a statistical analysis of what might go wrong with this system, and what might be the effects of it going wrong in that way, and you just go through literally thousands ways that this system could fail and what you think the effects will be if it fails and how often that it might happen? And get some MTBF (mean time before failure) and that's a statistical failure of how safe or dangerous this is. In 1000 hours of this working it may go wrong once or some statistic like that, and therefore*

4 Asimov's 'three laws of robotics' are 1. A robot may not injure a human being, or, through inaction, allow a human being to come to harm. 2. A robot must obey the orders given it by human beings except where such orders would conflict with the first law. 3. A robot must protect its own existence as long as such protection does not conflict with the first or second law (S. L. Anderson, 2008).

> *causes severe injury or death and that is deemed acceptable or not acceptable, if it is not acceptable then we go our way and redesign it and try again. Legal doesn't work like that. It can just happen once, it is legal or illegal and that's it. There's no proof statistical legality."*
>
> — P1T, Robotics Deputy Director]

Now, if we view the probability approach from the perspective of law, to what extend is the acceptable risks and the practically reasonable measures? Firms may be able to identify the level of risks, but the challenge still lies with the volatile risks of human-robot collaboration. This also goes back to the point about definition of law and lack of clarification as the senior lawyer P8L pointed out,

> *"The design of system really with safety law certainly in the UK is you take risk base times probability, and that is what you have to do because you're designing parameter of failure in advance. The use robotics will have multiple repetitions, for example, 1 year life of a robot in a manufacturing facility, so what is your failure mode and how do you deal with probability?"*
>
> — P8L, Partner (Law firm)

There is room for error in science but in law there is no such thing as margin for error, if life is lost or accident happens, someone needs to be responsible for the damages. it is not trial and error so proving safety from the legal perspective can be difficult from design. When the law is vague and focuses on 'do no harm', this becomes difficult to determine what is the acceptable risk. This may lead us back to the point of market as a regulator in the case that the companies just have to arrange a contractual agreement on what is acceptable risk. However, this will still cause issue from tort law perspective which will be explored further in Chapter 4 and in safety theme Section 3.3.8 and design theme Section 3.3.9.

The objective of this exploratory study is to investigate if the law the key barrier to adopt. In drawing together all the arguments ranging from the law is catching up with technology, the need to harmonise legal frameworks, and to bridge to the responsibility gap, there is another way to look at this problem. We have concluded to settle the current regulatory dilemma; this Study suggests that the law should come first and technology adoption will follow. It appears that safety is still one of the key factors to adoption and law can play a big role in building a supporting system to facilitate the growth of Cobot adoption. Therefore, the level of safety will need to be clarified and potentially redefined. Regulators may consider the use of design fiction to help depict the desirable as well as possible future of Cobots (Pólvora and Nascimento, 2021). As we start to see new proposals on regulating emerging technology whilst realising the impact and risk, we are one step closer to concluding the debate surrounding law stifling innovation as it will be technology developing to meet the law as P13L puts it,

> *"I think that's a great place to interrogate of whether that's a function of technology. Technology just isn't safe enough versus a legal problem.It's important to ask ourselves whether what is the hurdle there? Is it technology or is it really law?"*
>
> — P13L, Technology Law Professor

3.3.4 *Theme 3: Data and Privacy Concerns*

Data and privacy challenges are not problems uniquely to Cobots. Privacy concerns are one of the prominent issues with connected technologies since the introduction of the internet providing the data collected by these technologies that could be invasive to individual personal lives. Privacy challenge in relation to data are discussed widely (Edwards, 2016; Dashti and Ranise, 2019; Henriksen-Bulmer et al., 2020; Gellert, 2018; Janssen, 2020). However, Cobots present a different angle to this topic. Cobots are viewed as tools allowing for human-robot collaboration. The technology is not designed with the purpose to specifically monitoring users unlike some of the smart

IoT devices such as smart phone, smart watch, and smart thermostats. However, the use of sensors has become crucial in robotics to let the technology gather data to perform its tasks and interact in a safe way with its environment (Bdiwi, 2014; Avanzini et al., 2014; Fryman and Matthias, 2012; Wachter and B. Mittelstadt, 2019). However, this leads to increasingly problematic privacy issues given the constant interaction of robots with humans (Leenes et al., 2017a). In this section, we explored data and privacy challenges posed by Cobots from the perspective of the data collected by autonomous systems and the privacy aspects of employees. The conversation has a strong link to the regulatory challenges in the perspective of data protection regulations and its interplay with other regulatory frameworks in dealing with data collected by Cobots. Within the discussion of data protection, experts view that data minimization principle will likely be challenged by the liability regimes given the contradicting approach to data storage. Consequently, as Cobots will be used in the workplace context, some of the key issues with data protection regulation are balancing "between legitimate interests of employers and the reasonable privacy expectations of employees" (Article 29 Data Protection Working Party, n.d.). Understandably, privacy concern is mostly towards workplace surveillance as Cobots are constantly interacting with employees in close proximity it is very likely the technology can be used to also monitor employees. We presented these challenges by starting with the discussion on data and privacy concerns of the Cobot adoption and followed by the interplay between data protection and other legal doctrines.

3.3.4.1 *"I Spy, with my Little Sensor"*

What data is collected and captured by the robots?[5] Concerns around data privacy may not be a legal challenge from the perspective per-

5 This subsection clever title is from Professor Schafer and Professor Edwards' article *'"I Spy, with my Little Sensor": Fair Data Handling Practices for Robots Between Privacy, Copyright and Security'* (Schafer and Edwards, 2017) which captures the discussion of this section perfectly.

sonal data but rather a commercial data challenge. To start this debate, from a technological perspective, Cobots are capable of monitoring and recording all the interaction with the human workers. However, to function and perform the tasks assigned to Cobots, it is not necessary for Cobots to capture and record everything as Robotics and Automation Expert explains,

> *"I think it depends on what you're capturing in terms of data. From a robotic point of view, all we're capturing at the moment is things like throughput and sort of breakdown alarms. So not something that would come under GDPR as it's not human related. Now, moving forward, there is an anticipation that we will be looking at linking it into our production planning system, but it's still not personal data. But it could be business sensitive information in terms of throughput volume speeds so [our] competitive advantage or competitive disadvantage if it got out."*
>
> — P15M, Robotics and Automation Expert

What data is collected by robots will depend on the organization, but someone will be in control of what is collected as well as how it is being used. The adoption of Cobots present new ways for data to be collected given its interaction with human workers and other software and systems within the space of manufacturing. As we discussed earlier, Cobots are part of the DMT adoption in the transition into smart or connected factory and manufacturing process. Therefore, it is not only what Cobots are collecting but also what data are they sharing with the wider systems and how that should be managed. It may not be personal data as P15M mentioned but commercial sensitive data needs to also be kept confidential and how to approach this with multiple integrations of devices and software is another challenge from the perspective of data management. This challenge is highlighted by technology lawyer P12L,

> *"All of thought to go into how you control data that is collected during the process. And that will be personal data but also kind*

of that commercial data in terms of the layout of the premises. I think with robotic you start to introduce more opportunity for data to be collected in different ways. And knowledge is power. I think there's a really interesting discussion in a world that's increasingly driven by data and you have more innovative ways of capturing data, how do you protect the things? As lawyer we hold fundamental like confidentiality. That is something that we do on a daily basis, now we have many different software products and many different kinds of support and maintenance and you have to be able to manage that and create confidentiality in that linear environment – I think that doesn't necessarily create legal problems, but probably drives the change in business models, to how you manage new technologies within your organization."

— P12L, Senior Technology and Data Protection Lawyer

This challenge ties to the discussion of how much data should be collected which can differ from the legal perspective and design perspective. Technology needs to be functional and sensors are necessary, but this allows for the opportunity to gain insights of employees such as their performance level and productivity. It can be argued that the collected data is required to train robot as part of feedback loop approach, however, where does the line need to be drawn? To address this question, how data is collected and used in the workplace by the robot are the same questions for all technology used in the workplace. However, this highlights the problem of power asymmetry and what counter measures employees have to ensure their privacy is respected without tampering with cobot functions as data protection lawyer P12L clarifies,

"Even if the technology is not meant to be there as your workplace surveillance, but [cobot] will be interacting with people and potentially roaming around the workplace and indirectly you can still obtain data about the employees. There's a great opportunity for that to happen, but I think these things should

> *be seen as an evolution rather than anything else. It's not too dissimilar from how we control how swipe card data is used and CCTV data is used. But I think having the understanding of it is really important and then be able to have those discussions about how that data is used. And that will come up, wearing my hat as a data lawyer, one of the things I'm often asked is around, can organizations use CCTV footage? Can they use different body worn cameras on employees? I don't necessarily think there's a great leap, I think it'll be more of a transitional change. It's the question of rebalancing, also our rights and duties with regards to robotic entities. So what measures am I allowed to take in self-defense? Especially if they can be dangerous to third parties. For instance, think of CCTV face spray that makes me invisible for a CCTV camera, that's okay probably at the moment still if I do it on the streets. So, purely passive countermeasure against police surveillance, for instance, very small, possible limitations. If I were to do that at the workplace and suddenly one of the machines, as a result of that, causes a mess of and destroys property or human life. So you might have to rebalance a lot our behavior in a cobot environment."*
>
> — P12L, Senior Technology and Data Protection Lawyer

Data processing under legitimate interest basis such as safety of users is a complex argument. Although certain level of data processing may be permitted but this discussion becomes a conversation beyond of what the law should permit. More attention is required about how to protect the fundamental rights as generally technology is becoming more privacy invasive and people do not have a choice but to allow it as law and technology expert P7L highlights,

> *"In the traditional data protection problem that you think of Facebook and Google and whatever, there's still an element of choice, might be a very limited element of choice, but I typically have to do something for my data to be collected, I have to make use of a service. But in the robotics environment, especially in*

> *the workplace, that moment of decision making just doesn't exist any longer. So I'm increasingly involuntarily and without any choice in that matter, for us to collaborate in the data gathering. There's a massive and more problematic use of privacy invasive methods, which can't any longer be dealt with adequately through consent or some of the other legal mechanisms."*
>
> — P7L, Law and Technology Professor

Technology consultant P4C also voices the following concerns: *"anything that brings more sensors, cameras and microphones close to the human person has a privacy challenge because what you are doing is you are starting to gather more and more types of data. As you do that, that data is radioactive, that data is very revealing and intimate."* Several experts are cautious about the potential metadata that can be gathered by technology and discuss how DMTs and Cobots may increase surveillance in the workplace in a similar manner to other security technologies used to monitor employees. For example, P3C explains,

> *"I think the security and privacy thing is massive. I think people worry now about Alexa listening into what they're saying. But if you look at the combination of 5G, which I suppose is another emerging technology, but for me it's more of an enabler. Given the combination of 5G, you can have microphones and all your lamp posts, Triple CCTV and call yourself a smart city. The amount of data that's collected, you know, massively increases that security and privacy challenge."*
>
> — P3T, Chief Technologist Officer

This concern is also voiced by our survey respondents with both shop floor and managerial employees agreeing that surveillance and performance monitoring has increased. Although shop floor workers think that surveillance increased more than managerial respondents, this difference was not significant ($U = 2907.50$, $p = 0.889$; Figure 3.4).

Although one could argue that as required by data protection legislation, people should have a choice on how their data are being

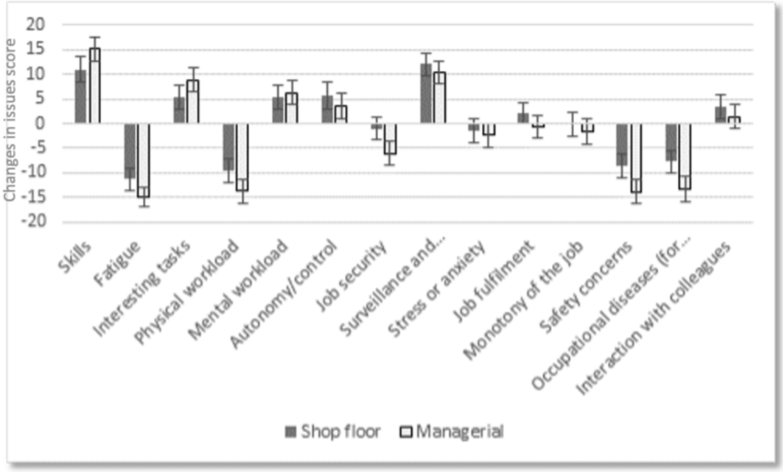

Figure 3.4: Issues around DMT and robots after technology introduction as a function of the employees' job role.

collected and used, data processing at work is a complex issue determined by the power imbalance between employers and workers. Despite their concerns of how emerging technology can become privacy invasive, employees may not be in a position to make choices without any ramification. With cobot's reliance on sensors and cameras to collecting data, employees may perceive that their employer tries to monitor and gain control over every aspect of their moves through overly invasive surveillance. Research found that constant over-monitoring of employees can also lead to an increase in stress, anxiety, burnout, and overwork—adding to more psychological and physical welfare issues (P. V. Moore, 2018; P. Moore and Piwek, 2017; Holt et al., 2017; Montealegre and Cascio, 2017). On that account, privacy and surveillance concerns need to be unpacked and addressed with Cobot adoption, as they can negatively impact employees' well-being.

3.3.4.2 *Dealing with Data: the Role of Data Protection regulations and other legal implications*

Following the conversation on data protection regulations, at the core, the regulations are aimed to protect individuals from harms due to the processing of their personal data. This protection has a great implication on privacy, but data protection compliance alone does not necessarily mean that harms related to data and privacy are not being perpetuate or completely eradicated but it presents a form of control and governance of data processing. A discussion on data protection is unpacked further in Chapter 4. To start the conversation on data protection regulation, law and technology expert P7L provides a good analogy on how the current legislation in the EU, the General Data Protection Regulations (GDPR), is enforcing data protection. GDPR is viewed as an outcome-based approach where organisations need to implement safeguards and measures to ensure that data are protected, and it is within the organisation's responsibility to establish such methods.

> *"The sort of the way I see it as similar distribution of responsibility, that you would get in the military, the officer or the general will tell you which kill to take, but it's up to the sergeant to decide how to take that kill. So, data protection, you have to keep the data safe. No ifs and buts. But how that can work in practice and how you can beat to the bone that could involve industrial mixture of industrial standards, ISO, training requirement, design solutions, open repositories, lots of things you can then decide to say 'I think we now can confidently say we are compliant. We do the things that overall objective keeping the data safe and that required of us'"*
>
> — P7L, Law and Technology Professor

The threshold for what is considered safe is still debated which we dove in further in Section 3.3.8. Consequently, in dealing with data collection by the robot, the GDPR outlines individual's rights as data subject; however, as this could potential interfere with some of the objectives on data collected by Cobot objectives such as using data in training robots, companies may try to arrange contractual agreement with employees where they cannot exercise their rights without repercussion. Companies will try to use the contractual power to overcome certain restrictions enforced by the GDPR. Due to the power asymmetry, employees are unlikely to have equal opportunity to negotiate for the agreements as P7L explains,

> *"You can't sign off that right, so you can't give it up. But I can't see a prima facie reason at least why you couldn't contractually agree not to use it... a very topical example is freedom of speech. Very obviously, my freedom of speech is limited once I enter an employment contract. If I say certain really, really nasty things about my employer, then they can fire me - not a violation of my freedom of speech right. They can also fine me or we can agree something else that should be a penalty in that case, but that doesn't mean that I lose my freedom of speech. So you would possibly put something in, 'I agree not to exercise my right for data portability for information that my employer gathers, my employer will use it to certain commercial degree or something. And the penalty will be I have to pay that additional money back for the exercise my right nonetheless.'"*
>
> — P7L, Law and Technology Professor

Although the GDPR may appear to the extensive legislation in dealing the challenges of data and privacy, experts find that there are more considerations on the implications of the data protection on other regulatory regimes. There are contradicting approaches between data protection principle and liability model in data storage for example P7L explains *"the liability lawyers in the company will always suggest to keep data as long as possible as a form of evidence, but from a data protection perspective that is problematic."* To avoid liability, organisations are likely to be more eager to store the data for as long as possible into to present evidence in the case of harm caused by robots which undermines the data minimisation principle of data protection principles. As liability is a big issue with robots, therefore, data will be the key when something goes wrong to autonomous systems.

In consideration to data, there needs to be more explicit discussion about the type of 'data' collected by Cobots as this will be the key indication of which legal framework will apply. As a senior lawyer P8L points out, *"there is a matrix of different legal frameworks. You got the liability framework, what are the rules and what are compensatory. Everybody is talking about data as though it is homogenous but you have different categories of it: personal data, sensitive personal data, and intellectual property, trade secret, and confidential information?"* Providing a wide range of data, this creates a com of dealing with commercial data obtained by the machine whereas in some cases such data can be classified as both personal data and commercial data. This overlap can trigger a gap in different regulatory frameworks in particular data protection, intellectual property law, and labour law in determining the ownership over the data the robot collected and how can the data be used. Consequently, it creates an entanglement of potential beneficiaries from the data collected by Cobots in the workplace from the employee to employer to Cobot provider. For example, through the interaction with Cobots, human workers simultaneously teach the robots on how to perform certain tasks. These interactions are collected as data which can include the extensive recording of employee's voice, facial expression, gestures, and movements. Therefore, data collected by Cobot can be considered as personal data which subjected to the GDPR and theoretically the employee should have control over how such data is collected and used. However, it can be argued from the perspective of legitimate interests of the employer as the data controller that the employee is required to work with robots and thereby the training is part of their responsibilities. In contrary, it might not be permissible under copyright law. At this instance, a human worker might have the exclusive rights as the creator of the data sets with a control over the use of their recorded data and the ability to get compensation if it is used to train robots. Therefore, the use of personal data might be permissible from data protection perspective but problematic from intellectual property law and employment contract as law and technology expert explains,

> *"Assume that this robot takes the snippets of my voice and uses them as feedback and creates a better voice recognition as a res-*

> *ult. I have copyright in what I said. Through an employment contract, my employer has the copyright for the work that I create but this is a suddenly now really becoming copyright law issues. So, I might say, 'yes, you're allowed to process for the purpose of workplace safety and doing my job. But at the moment you gain an additional commercial value out of my speech and to get re-compensated as that is not part of my employment contract, that is going above and beyond what I'm obligated to do.' There you can see, even though this is okay, from a data protection perspective, there is still a potential alternative obstacle here. Some may say this is protected by copyright and even if under employment law, my employer has the right to use this, maybe even to commercially exploited, there are still the moral rights of the author. IP right matters here on its own terms, and it might prevent use of data that is permissible under Data Protection Law."*[6]
>
> — P7L, Law and Technology Professor

To further complicated the matter, data introduces higher risks of cyber security attacks where the regulatory approaches are required to be put in place[7]. Although there are clear legal requirements under the GDPR, Computer Misuse Act, and the Network and Information Security Directive to protect personal data such as appropriate technical organizational measures, however, there is a lack of protection on the case of commercial data, compliance issue arises P12L,

> *"There isn't anything where there's a kind of clear law about how you deal with malicious cyber attacks, or how malicious actors using technology as a way to access data or prevent access to data that they shouldn't even be touching upon. And I think that's one of the things that we need to look at addressing. It feels like a gap. And a gap that's been slightly plugged*

6 Read the full quote from P7L Appendix B

7 Since the Study, in 2022 the EU launched Cyber Resilience Act *See* here

> *in terms of what GDPR says about personal data. But we're talking about systems that hold data that's much more than just personal data. It is absolutely right that personal data is protected. But we're also talking about commercial data and sensitive commercial data. And I think we're kind of missing from the protections around that."*
>
> — P12L, Senior Technology and Data Protection Lawyer

Nonetheless, it may be feasible to address this challenge through contractual agreement, but the challenge will be determining who owns the data what given the conflicting demand and interest for data ownership. As manufacturers consider adopting Cobots, they are going to be in the position of 'customer' where they are providing valuable data to help train the robots. The question will then be if the robots advance given that they are trained on the data provided by the manufacturer, does the cobot provider company own the data where the company can use the data to further train new robots with? Data ownership is a concerned for both technology adopters and technology providers. Technology adoption consultant P9C points out this challenge from their perspective in working with technology provider of microchip that contractual agreement will need to be put in place to address data ownership,

> *"In terms of a legal issue, one of the other aspects could be that the customer is providing some intellectual property into the product. [For example] my robot worked with Charlie, and it really does what Charlie wants it to do, and it's fantastic. Charlie could then say, 'well, actually, you know, I taught you how to do this. This is my IP.' In previous career, when we've been developing chips for customers. You absolutely must have customer drivers to tell you what they need and you really do need to sort out who owns what, in terms of the value of the product. If you don't do that, you are open for customers to come and sort you out."*
>
> — P9C, Technology adoption consultant

Dealing with distributing data collection by technology perhaps is not something new from business-to-business point of view. Therefore, it might be expected that the standard practice in dealing with Cobots will not deviate from the current protocol as contractually arranged first as already mentioned above by P9C, but it is important to take into account different data points and how to map out who is collecting and accessing. Taking into account of robot maintenance, organisations who look to adopt Cobots will need to be aware of what data the robot provider has access to as such assess may be connected to the organisation's internal environments. The access to data by the third party raises risks on system's privacy and security, making it vulnerable to cyberattack (Yeboah-Ofori and Islam, 2019). Therefore, allowing for access to the live environment of Cobots will require a thorough discussion and should only be allowed if there is a critical issue. Conversations on data access need to be made clear during the contract negotiation with the robot providers as data protection lawyer P12L advises,

> *"I think it will be the standard position as to what data is collected and what level of access does the vendor have to that data. It's assessing the risk of something like introducing robotics in terms of what are the vulnerabilities. I think that comes back to kind of security and control. If you have the ability to exercise control over a robot, for example, robotics that you have in the workplace, because potentially looking at a scenario even though they are compliance with all applicable laws in your industry, do you want to give that much control to a vendor, and I think it depends on the controls that they put in place as well as do they have access to the data collected by the robot? If they do, is that real time data, what level of encryption is there? what data is the robot collecting? And importantly, how long is it retaining that for so if it is programmed to only collect specific data fields?"*
>
> — P12L, Senior Technology and Data Protection Lawyer

We have walked through an extensive discussion on the regulations of data collected by Cobots from the perspective of personal data under data protection regulations to commercial data under intellectual property law. However, in conclusion, despite the fundamental of legal debates, it appears that commercial arrangement will likely be the solution to address the data governance and ownership. Similar to Lessig's model discussed under Section 3.3.3, market will likely help regulate how Cobots will be used including the data collected by the technology.

3.3.5 *Theme 4: Define Due Diligence*

Although the manufacturing industry is no stranger to robotics and automation, the adoption of Cobots poses new challenges particularly from a workplace safety perspective. Robotics in manufacturing is heavily regulated but there remains a question of whether the current standards are appropriate to govern the implementation of Cobots as discussed under Section 3.3.3 section. However, there are strict policies on safety protocols, such as, physical barriers, sensors and other systems to prevent people from being in close proximity to the robot while it's working and to ensure that the robot automatically stops when people are within certain range. But isolating Cobots in cages or requiring a cobot to stop when a human worker is near will entirely defeat the purpose of Cobot adoption. Employers are obligated to perform due diligence under Health and Safety at Work etc. Act 1974 and The Management of Health and Safety at Work Regulations 1999 to ensure workplace safety. However, the specifics on the level of due diligence performed and the risks in implementation, is up for interpretation, which is problematic with smart technology and its unprecedented risks. Currently, the only unconventional form of regulation with clear guidelines on the safety Cobots design is International Organization for Standardization, which is available as a guideline for Cobots safety measure through its most recent technical specification (TS 15066) which still does not allow for human-robot collaboration (Robotics, 2016). This section explores how the term 'due diligence', in relation to the process of technology design and implementation, is practiced by different experts who are also the key stakeholders for adoption of new embodied intelligent and autonomous systems in industrial workplaces. Whilst the term 'due diligence' is referred to by various experts, the meaning is different from one expert to another. Some say that minimizing risk is equivalent to doing your due diligence while some say that due diligence is merely to comply with the legal requirement. Therefore, due diligence does not only concern safety assurance or regulatory compliance but rather a relationship between understanding of law, risk management, and design of technology.

3.3.5.1 *The Ill-defined Parameters of Due Diligence Practices*

What does it mean to carry out 'due diligence'? Bonnitcha and McCorquodale addressed the two distinct concepts of due diligence knows as a business practice especially as part of merger and acquisition practices to reduce business risks and due diligence as a conduct required in obligations of the law (Bonnitcha and McCorquodale, 2017).The two concepts speak differently in term of the requirements for due diligence practices. In the context of Cobot adoption, the latter concept is more aligned with the discussions with the experts. Due diligence as a conduct requires further refinement on the parameters of the term and in what context such practice applies. In the first context, due diligence is viewed from the perspective of workplace safety. When Cobots are integrated as part of the manufacturing process, employers have the obligations to ensure workplace safety as part of due diligence practices. The uptake of Cobots requires a big shift in risks assessment. Although suppliers may have certain certifications to ensure a level of product safety such as the CE marking which is a certification mark that indicates conformity with health, safety, and environmental protection standards; however, Cobots pose the new realm of safety and liability challenges as discussed in 3.3.2.4. Therefore, cobot adopters (i.e., employers) are facing difficulties in demonstrating safety in the context of human-robot collaboration and therefore it is better to keep Cobots behind the cage. An innovation expert highlights,

> *"In the event that I am the employer, I am liable. And that is the stance that company would take because fundamentally, there is a requirement to CE mark on something. And the CE mark is not about the technical operation per se. It's only about the efficacy in the operation of the equipment. And it's how I integrate that equipment into my business, so in cooperation that could potentially fundamentally change. So that robot come with CE marks. They don't need cages to get their CE mark. For operationally safe, they do need cages. So the difference in getting the CE mark is 'is the equipment capable of doing it? Yes it is. But if a robot can hurt somebody then I've got a cage in."*
>
> — P14M, Innovation Manager

Consequently, experts see that due diligence must be done to prove the degree of reliability for the product. In this case, it places the expectation on the cobot provider to ensure that Cobots are safe and suitable for its purpose as technology lawyer P12L puts, *"many of the products I see on a daily basis, there is a degree of reliability on the software vendor to have done their due diligence on the products that they're launching. For my perspective is the due diligence on the products as their compliance to the customer environment.""* Furthermore, the essence of due diligence can be viewed as 'do no harm' which therefore signifies the term as having a plan on how to go about demonstrating a systematic mechanism to achieve such objective. This objective needs to be carried out throughout the lifecycle of Cobots with starting from the development to the deployment of Cobots. Harms can be difficult to identify; therefore, Cobot providers need to take a systematic approach in assessing the impact of the technology. The factors of harms need to be explored from the design of Cobots as well as from the perspective of human-robot interaction. Because Cobots will be working and interacting with human workers, it is highly important that cobot providers and adopters perform thorough due diligence on the safety of the interaction as much as the technical aspects of safety. As P14M discusses above, CE mark only certifies that the product meets certain standard such as the efficacy in the operation of the equipment, but it may not reflect the operational or the integration side of the technology. Therefore, 'do no harm' as the due diligence objective will need more than a technical standard but also the operational safety element as this is captured by technology and ethics expert,

> *"the due diligence that applies closer to the legal definition of it that demonstrates an organization has done everything in its power to make sure that it is systematically avoiding all possible harms. So it has to go back to the concept, the pre development that brings open that whole view of who can possibly be harmed by this? And do we even want to develop this product? If we do, so let's say they get passed that gate minutes ago. So who's it going to harm? How do you mitigate all those harms? And how can you reduce that mitigation so that nobody is harmed?"*
>
> — P6C, Responsible Technology Consultant

Following the do no harm approach to due diligence, the threshold on harms is succinct. Therefore, experts highlight on the element of human factors aspect as the basis of Cobots design to ensure safety. When integrating Cobots, the technology may work perfectly in one scenario but the collaboration element between human and robot means that Cobots will interact with different environments and people. Therefore, the involvement of wider stakeholders in cobot design is required as part of due diligence though it is currently missing.

3.3.5.2 *Designer Due Diligence*

Following the discussion above, with the unclear parameters of due diligence, experts see that the current challenge lies with the competitive technology market and the lack of adequate safety standards for Cobots in considerations to the involvement of wider stakeholders and users in testing human-robot interaction. In the first part of the due diligence challenges, experts recognise the influence of the high market competition in rushing to the market. The technology lawyer P12L highlights *"some technology companies rush to market essentially without having done necessarily due diligence because it's a great product and it delivers."* Although this reason provides a form of explanation of the ubiquitous unsafe technology, though it is alarming for Cobots where the machine will be used in industrial setting for high risks activities with strict safety protocols. Therefore, the due diligence practices from design stage to adoption phase must be redefined to set a new standard where involvement of stakeholders is required.

In this discussion, the technology ethics expert P6C mentions then when it comes to challenges with robotics, companies are not performed due diligence or at the point that they should be doing. Secondly, with the design of the system, from the beginning, there's not so much of reaching out to stakeholders and ensuring that the system is ethical. And even though companies follow the existing standard but there is a problem with standards because the standards themselves are inherently biased. P6C also highlights that the actual testing of technology appears to be after the product is launched which is inadequate.

> *"So you see the apps come out now and user community is giving the feedback and doing the testing. That is the rapid change in terms of development that developers no longer have to take the risk responsibility for what the code will do and just wait for the feedback from the user. In the case of robotics and safety and security, and so on, by that point, it could be too late."*
>
> — P6C, Responsible Technology Consultant

This discussion implies the need for better standards and guidelines to help establish level of 'due diligence' by requiring the involvement of wider stakeholders, especially end users, rather than leaving this to the industry to determine what is enough. However, one of the barriers in addressing this standard is cost. As the technology adoption consultant P9C claims, *"because it may slow the development cycle, it may increase the cost development to run events or get customers involved and all those kinds of things that's possibly true."* Although it is the ethical thing to do in term of increasing the safety standard, however, technology providers may still choose to do the bare minimum considering the cost as technology ethics expert P6C also explains,

> *"But they have to want to do that; they have to invest the money because it means doing a risk assessment prior to development, as opposed to afterward, and to be able to say that "sorry, the technology is too immature. We should not go ahead with this until we know more." Now, whether or not they're willing to do that, given that they're asking for additional overheads to be injected into the process. Because every time you have to reach out to more stakeholders, it has to cost your development cycle more."*
>
> — P6C, Responsible Technology Consultant

Nonetheless, in achieving safety of human-robot collaboration and taking on the 'do no harm approach' of due diligence, we must advocate for stakeholder involvements. The consideration of the end users and how the Cobots are trained in a collaborative environment will impact the safety of this technology. Therefore, adequate training and evaluation methods need to reflect a wider interaction between human, robots and the environment as technology expert P3T argues,

> *"A big issue with algorithms is hidden inferred variables that aren't explicitly fed into the algorithm but influencing it. If you're designing systems for mass production, one of the key things in the design process is to have diversity of viewpoints. From a person deploying that kind of technology perspective, what I would be most worried about is other human actors operating within the same domain space. When you are talking*

> *about reinforcement learning you are taking knowledge from observing one particular human, and then you're trying to replicate that in a physical space collaborating with a different human. Have you considered the differences between those humans and what if it's a disabled person? How do you make sure that not only the one person that the robot is focusing on is free from harm, but anyone else that the robot is not focusing on but is in the same space. There are well known concerns in the ability of computer systems to sense the environment with different types of people. So, color of skin, type of face, etc, can lead to mistakes, either because of training data, or because of basic differences in pigment and how the light falls and things like that"*
>
> — P3T, Chief Technologist Officer

In enforcing such requirement, it can be postulated that the law can put in stricter rules to demand more due diligence performed and this needs to happen now. Providing the rush to the market element, it might not be possible to leave it to the market to regulate as the technology ethics P6C sees,

> *"And if you're looking at a profit based scenario, that's highly unlikely going to be occurring because that means the competition gets the head. So it's kind of in a no win situation with respect to this until regulators start to put some force into this, then we're going to end up with Facebook of robotics. In other words, absolutely no control."*
>
> — P6C, Responsible Technology consultant

This discussion aligns closely with the regulatory challenges as it is recognised that law plays a crucial role for a responsible design and adoption of Cobots. Nevertheless, the law and technology expert P7L thinks that professional codes of conduct or professional ethical standards as a form of legal instrument can be a solution to uphold due diligence and ethical practice for technology designers;

> *"So that's a discussion that at the moment is starting to take traction beyond work environment and Cobots. In the past, they were always certain professions, which should be considered so important for society that they have additional regulator and professional standards, the medical profession, the Hippocratic oath and General Medical Council in the UK, the law societies as regulator of the legal profession. So codes of conduct that are actually internally enforced and can result in loss of the license to practice. So that I think, is one of the things on what one should consider here to say 'if I'm working on these things, I have dual obligation on the one hand to my employer or my client, but also to my professional body.' So I think there's a stronger need now to professionalize the computer science workers and create professional bodies that are not trade unions and that are not representative members, but as the disciplinarian. I think that is potentially one of the development that we might see."*
>
> — P7L, Law and Technology Professor

Overall, due diligence starts from the safety of Cobots. Employers when doing due diligence as part of workplace safety will need to appraise for the companies that are up to standard with the standard being technical safety as well as the demonstration of the testing on a wider range of users. Cobots cannot only be safe to work with humans 'if' the person is a white male over 6 feet without glasses with a British accent. Cobots must work safely with all operators without ifs and that should be the threshold of designer due diligence.

3.3.6 *Theme 5: Rethink Risk Factors*

We have established in Section 3.3.5 that due diligence as a requirement implies a need to minimize and mitigate the likelihood and impact of potential risks associated with the process of technology design and implementation. Therefore, the discussion around due diligence comes to light with the understanding of cobot related risks. In this section, we observe that 'risk' is twofold within the context of design and adoption: what risk assessment is considered appropriate to take and what is the acceptable level of risk. Cobots as emerging technology introduce manufacturing sector to an unfamiliar space where robot and humans work in the same space without a barrier. The risks of such interaction may be difficult to gauge given the novelty of the technology and thereby creates a gray area for risk assessment. Thus, this section unpacks the challenges in identifying new risks in relations to Cobots for both technology designers and adopters and the need to rethink how organizations should assess and approve the acceptable risks of human-robot collaboration.

3.3.6.1 *Risk Assessment Approaches*

In essence, the scope of risks can be summed up as understanding and predicting how things might go wrong and what actions can be taken to mitigate them.

> *"As you introduce robotics into the workplace, there is a potential for huge increases in cost savings and efficiencies. But you also have to provide those situations where it doesn't do what it says it's going to do and how you manage that in terms of how businesses able to respond to that? It's understanding what happens if things are going not so well and you've got an issue and how do you manage that from finding out about it to written resolution?"*
>
> — P12L, Senior Technology and Data Protection Lawyer

Therefore, a risk assessment is a standard practice or technology development and adoption. However, the approach to a risk assessment is varied. In exploring this topic, we found that the risk landscape of technology adoption is a multi-dimension. Although safety is typically the first form of risk to consider but it is not the only risk factors for technology development and adoption. When assessing the risks of emerging technology, organisations need to consider the broader implications of the technology with the anticipation of potential ramifications. Technology ethics expert P6C highlights, *"they need to perform risk management of every stage, without question. Start to anticipate where these things could go wrong so that the mitigation can be put in place up front."* Consequently, it is essential to consider various aspects of technology development when analysing the risk factors. As technology lawyer P11L advises,

> *"Because things go wrong, it's impossible to guarantee that nothing will go wrong. The common starting point for risk in practically everything is safety, that comes fairly naturally from looking at most kind of tech applications as products. Beyond that, the risks can start taking in different ways. Regulatory risks, so what disruption, is this tech or product bring about? Then you start looking into commercial risks, to what extent does this start disrupting or challenging commercial models? Indeed, could it ever be viable as a product? And public policy risk, overlay on top that, is that the technology may be great, but actually, it may be fairly unacceptable to society for other reasons. And those can include the kind of socio-economic risks of losing jobs."*
>
> — P11L, Director of Law and Connected Autonomous Vehicles

Whilst this statement pertains to cobot providers, the same principles apply when it comes to adopting the technology. Furthermore, the method used to assess risks may differ depending on the operational sector. Manufacturing expert P2M explains in the case of automotive industry on assessing the adopting Cobots,

> *"What they would build before making a decision is what is called FMEA in the automotive industry is a failure model analysis and then taking into account the expert on the laws. Every restriction we have to build the analysis of all of these risks, how these risks can be managed then to define a plan of how the Co-*

> *bots are able to stop or not to damage human beings they will work together."*
>
> — P2M, Quality Director

The approach taken by industry tends to concentrate on the failure of Cobots and the safety aspect as well as how the risks will be managed. The mitigation strategy requires a fair understanding of the technology as a technology lawyer P12L highlights, *"I think managing risk is a really important factor. Understanding the limitations of the software as much as kind of what it can do for you, is really key."* We have discussed in Section 3.3.2.4 where the challenge with new technology like Cobots are the misunderstanding of the technology or the lack of knowledge about the technology. This creates a gap in risk assessment in a similar way to the legal discussion on the unknowns providing the novelty of the technology. This poses the very same question of how do we mitigate the uncharted risks? As experts suggested, organizations must look beyond conventional risk assessment methods to conduct a comprehensive evaluation of Cobots. This involves anticipating and managing risks associated with Cobots throughout their entire life cycle, from design to the adoption process, acknowledging that something is bound to go wrong.

3.3.6.2 *Acceptable Risks*

Following the risk assessment discussion, the acceptable level of risk associated with human-robot collaboration appears to be varied. Risks are clear when human and robots are separated. Provided that robots are situated inside the cage or behind the barrier, the risk of human workers being harmed by robot is minimised and that tends to be an explicit acceptable level of risk. However, there is not a straightforward delineation of risks involved with human-robot collaboration. Certainly, the removal of barriers makes the risk become more apparent particular from physical safety aspect. Though, it is not evident to what degree the tolerable level of risk should be. There needs to be a balance between acceptable risks and functionality of the system because 'zero risk' is not possible, as a senior lawyer P8L states, *"because if you are designing your prescriptive standards for zero harm that is a non-functional system."*

Furthermore, risks with technology, as discussed in the previous section, are associated with various factors beyond safety. However, we still see that the conversation primarily focuses on safety-related concerns. The acceptable level of risk is also approached differently by various experts. Robotics expert views that the level of acceptable risk should be decided by the technology designers as opposed to a prescriptive standard solely decided by policy makers. This approach endorses the conventional idea of establishing a standard level of acceptable risks by bridging the knowledge gap and considering a broad spectrum of stakeholders, as robotics expert P1T argues,

> *"One of the things that they are trying to do is make government aware of the fact that there may be a need for a shift in the legal system. I'm not saying that it's okay for people to die but if you're going to try it make some technological progress there is always some attributable risk. It may be a legal system will have to move to a situation in which it is able to work with technologists to decide whether that risk is acceptable or not."*
>
> — P1, Deputy Director Robotics and Autonomous Systems

This statement truly mirrors the objective of this PhD thesis, which emphasizes the importance of bridging different communities together to gain a better understanding of Cobot adoption and regulation. Furthermore, the level of acceptable risk varies depending on the use case of the technology. In conducting assessment, presumably Cobots are tested under specific controlled environment. Although the level of risk is acceptable for the condition of use, but the level of risks will change depending on the real environment Cobots are put in. Therefore, there needs to be a clear indication of the controlled parameters where the risks are accountable for. Because the acceptable level of risks is not interchangeable for different use cases as technology ethics expert explains,

> *"there's never going to be a level of acceptable risk that's completely understood or agreed across the world. It's always going to be contextual, anyway. So in that situation, in this context of use, and controlling all those parameters, we can say it's safe, we can say it's ethical, we can say it secure. Change any one of those variables and that's what the public needs to understand where the worker or the operator change a single variable, that statement is no longer true."*
>
> — P6C, Responsible Technology consultant

The acceptable risks reflect the assessor's understanding of technology capability and limitation. This notion is closely related to the discussion on the transparency of the specification of Cobots as well as a clear communication with different stakeholders on the expectation of Cobots. Moreover, from the adopter's perspective, acceptable risks are manageable risks. This approach aligns with the requirement of controlled parameters of Cobots where acceptable risks are blatant. The manufacturing expert, P2M, views this issue as a primary challenge where the level of acceptable risks depends largely on a well-defined and unified risk assessment that is not yet established for Cobots.

> *"The challenge for us is how can we assure that we are not at risk by having them because at the end they're moving machine. But how we will be sure that they are not at any failure mode that we didn't take an account before. The challenge is to find a way to be sure of all the risk and we have checked all the risks are really manageable for the current cobot technology."*
>
> — P2M, Quality Director

Risk management and mitigation for the unknowns and the ability to understand the technology and its limit or failure points is key for

Cobot adoption. This discussion underscores the importance of bearing in mind that, despite their capabilities, robots are still machines. This raises the question of how much confidence we should have in them, and in some instances, how people may over-rely on robots while placing excessive expectations on their abilities. Therefore, the use cases for Cobots must be clearly communicated and thoughtfully planned for various scenarios in which robots can be employed, ranging from the cobot's operating environment to the end-users that Cobots will be interacting with. Because the use case will be used as the baseline for risk assessment, as the senior lawyer P8L asserts, *"the use case drives the risk assessment and risk assessment drives the level of standard and that is not contentious."* All in all, the acceptable level of risk is contextual, and the extent of risk taken depends on the sector involved. as a senior lawyer P12L explains;

> *"So, if our client operates it in the nucleus sector, then you're going to try to assess whether this security that applies to that software is sufficient for something that is kind of operating within the critical national infrastructure. But that will be led by client sector, kind of demand, their risk appetite and willingness to embrace new technology and try new technology."*
>
> — P12L, Senior Technology and Data Protection Lawyer

There is also a possibility that an authoritative source on acceptable risks can exert considerable influence on the sector's risk appetite as manufacturing expert P2M views,

> *"I believe the bigger the Cobots, the more afraid people would be at the beginning until they know that there is no risk around this technology. I know that in this (automobile) industry, they are more advanced. Maybe the government will speak about it and maybe it will be more easy for the demands to adopt and work with the Cobots."*
>
> — P2M, Quality Director

Whilst some experts acknowledge the significant role of technologists and business operation strategies in determining acceptable risks, the decision on what constitutes acceptable risk should not rest solely on the industry. Wider stakeholders, especially end-users, must also be included in the conversation due to the direct risks associated with the collaboration with Cobots as technology ethics expert P6C argues,

> *"It has to be contextual, and it has to be from the stakeholder perspective in order to avoid, 'well, I think everything's harmful so don't do anything' that kind of over the top thinking. You get some credence from law. There's been precedent there. You get some of the medical model that looks at the individual system in context, 'yes, I'm going to cut you off and I'm going to harm you, but you have agreed that that's okay because there's a better good and you're willing to take that risk.' And it makes a risk decision part of the stakeholder process. Because the whole part of risk management is you don't get to take somebody else's risk for them. That's not allowed. You're custodian of their risk potentially, or a potential perpetrator of it, but you do mitigation, so it's up to them to say that's acceptable or not, because nobody can judge for them."*
>
> — P6C, Responsible Technology consultant

This brings us back to the initial point on the indispensability of technologists and other stakeholders in the discussion of risks since there appears to be no one-size-fits-all approach or standard for the acceptable level of risks, as risks are determined by the context, whether it is the sector or the use case. Nevertheless, in the case of autonomous systems, managing risk is expected to remain within the realm of contract arrangements in a business-to-business context. Therefore, determining whether the risk is acceptable or not may rely on whether the product satisfies the business's requirements, and the risks allocation and mitigation will be managed accordingly. A senior lawyer P12L explains,

> *"The vendors will have their own lawyers as well. And what you're doing in the contract is you're assessing out the commercial terms, but you also do like risk allocation. If something goes wrong, if there's a bug in the software, if the software has a vulnerability that leads to client being exposed, who's covering that risk? I imagine that the way it will go will be vendors adopter position that says 'we build hundreds of these hubs of robots and they come in and they do this process. And this is our standard way that we contract.' That is very much how they do things now. And you can see the logic in that because they contract with hundreds of thousands of customers, the internal management time of having different sets of contracts for each customer. It just makes the business model unworkable. I can't see that they would vastly change their approach. I think you will still have the same commercial issues such as bargaining power. If a software vendor is huge and the customer is huge, then they want whatever is best for their business. I think that will come down as well to having quite clear scopes about what you are buying the services or product for and whether or not it delivers."*
>
> — P12L, Senior Technology and Data Protection Lawyer

Given the uncertainties associated with technology, contractual agreements are likely to play a crucial role in managing risks as we also see this in Section 3.3.4.2 on dealing with data ownership. Ultimately, the standardization or regulation of acceptable risks would require the involvement of various stakeholder with a particular emphasis on those knowledgeable in technology and its workings. The discourse on risks takes various forms, with approaches ranging from the idea that acceptable risks are conditional on predefined or regulated parameters to the notion that acceptable risks are viewed as risks that are manageable. Hence, assessing the risks associated with Cobots is a multifaceted task that demands additional exploration.

3.3.7 *Theme 6: Insurance as Adoption Gatekeeper*

Insurance is viewed as a form of mitigation plan and risk management. Although this discussion is closely tied to risk theme, insurance is acknowledged as one of the crucial factors in embracing smart technologies since autonomous systems. It has been recognised that liability in dealing with risks from Cobots such as safety risks are one of the key barriers given the financial ramification. Therefore, experts see that insurance and the law are the fundamental factors to build the system to support the adoption of smart technologies as robotics experts P1T and technology lawyer P12L point out,

> *"I think we will see iterations of that over the next however long decades how you deal with insurance and potentially some of the issues around liability where you have multiple stakeholders involved in developing products, big robots or complex AI where it looked at addressing some of the issues in terms of how you portion liability and responsibility, and how you address that"*
>
> — P12L, Senior Technology and Data Protection Lawyer

Dealing with damages and liability with autonomous systems can be complicated, therefore, insurers can play a role as the third party to investigate the incident as opposed to placing the burden on the organisations adopting the technology. For example, this model is put in place for autonomous vehicles where the regulations surrounding their use are becoming increasingly prominent. In the UK, Automated and Electric Vehicles Act 2018 makes insurance compulsory for autonomous vehicles (Automated and Electric Vehicles Act, 2018). Under this legislation, the insurers will be liable for damages caused by autonomous vehicles with certain limited liability e.g., the accident was caused by the person's negligence such using the car under unfitted-condition, failure to update software and altering software without permission. Thus, this model restricts that the insurers are liable for the damages only if the car is operating in autonomous systems mode, places responsibility on the owner of the car where they need to be vigilance in maintaining the car or take control when requires. In the case of Cobots, robot operators might be held liable for negligence and potential damages; however, if they followed the proper protocol and an issue still occurred, they should not bear any responsibility. This system should increase confidence in Cobot adoption. However, the mandate insurance for autonomous systems can potentially make insurance companies a gatekeeper for technology adoption. Scholars found that in case of autonomous vehicles, insurance companies can either be an enabler or the barrier to technology adoption as they can "promote or even push the technology by offering beneficial insurance models, or to undermine the whole undertaking by refusing to insure vehicles driven in autonomous mode" (Baumann et al., 2019, p. 2). Therefore, we anticipated that insurance will also be a potential challenge for Cobot adoption. It is a common practice for organisations to have insurance as the way to protect them against costs arising from potential liabilities and damages whereas insurance companies will need to devise new models to address Cobots risks. The changes to insurance model may increase or change the premiums and become an unwanted cost for cobot adopter. Technology lawyer P11L explains this by drawing a parallel comparison between Cobots and autonomous vehicles;

> *"Driverless cars are probably the first phase of dealing with potential legal issues between deciding whether, if something's gone wrong, was it a human, or was it the car at the time, who's responsible? The first way to look at it is always from the victim's point of view. You do not really want to be in a position where the victim gets dragged into that debate between the human operator or his employer and the machine and it's all manufacture. It's a huge high level very, very technical dispute. And currently, if you're hit by a car on a road, you have a very clear way of getting compensation. The EU have motor insurance directives of compulsory third party insurance. That isn't so that they can punish drivers and make them get insurance*

> *and pay for it. It's actually to protect third parties. The insurance needs to be able to cover what needs to be covered or most of operation as to who is operating at a time and then the dispute about whether it's user or product liability is then dealt with in the background. So you've been injured, you didn't really care whether the vehicle was driven by the car itself or one of the human, you will get compensated for that by the insurer, and then the dispute moves and the division of insurance arrangement whereby the insurer may be able to claim from the manufacturer that there was a product default. But as a highly technical, quite specialist process, and insurers are better equipped to deal with that than general public.* ***There is a bit of that in the sense that anything is insurable practically for a price*** *unless it's actually contrary to public policy, so it's illegal or whatever happens to be but assuming as a legal activity, it is possible to ensure subjected to premium being affordable."*
>
> — P11L, Director of Law and Connected Autonomous Vehicles

It is a big debate across different jurisdictions in response to liability for the damage in the case of an accident caused by autonomous systems connected autonomous vehicles (Alawadhi et al., 2020; Kubica, 2022; Pattinson et al., 2020). Thus, the development of CAVs industry can be used as a representative case of how the future insurance process could be for other smart technologies like Cobots. Nonetheless, insurance is viewed as part of technology adoption ecosystem to build trust and safety of emerging technologies, but it would likely to result in the increased, perhaps unwanted, costs for manufacturers in adopting Cobots.

3.3.8 *Theme 7: Safety Concerns*

Safety concerns regarding human-robot collaboration is not a new discussion (Baerveldt, 1992; Fryman and Matthias, 2012; Gleirscher et al., 2022) (also see Section 2.4.2. In fact, this is one of the known barriers to adoption for Cobots (Kildal et al., 2018). Safety has a direct link to liability and risk and this topic has appeared in the discussion throughout all the themes we have covered thus far. This section delves deeper into safety ranging from safety as the minimum requirement to determining what is the adequate level of safety in the context of design and implementation. Although safety is a minimum requirement for Cobots from all perspectives including legal, technical, and ethical, the standard for safety can be subjective depending on the stakeholders. The significant emphasis on safety resonates with the importance of due diligence in avoiding harm and the trade-off following cost versus risk analysis. Moreover, the persistent view on the separation of humans and robots as a safer alternative could potentially hinder the adoption of Cobots and prevent them from being utilized to their full potential. Nonetheless, experts view that striking the balance between functional robots and high level of robot safety is crucial.

3.3.8.1 *Safety as the Minimum Requirement*

Ensuring safety is a primary consideration for Cobots and one that is necessary for successful commercialization and implementation. When dealing with machinery, safety is always the first concern. From the adoption side, safety standard is in the case of cobot maintenance protocol with particular focus on sensors as the manufacturing expert P2M explains,

> *"To make sure that the sensors are working properly, we based the safety criteria on the sensors for how the Cobots can recognize the environment so the sensors cannot be in a bad condition. Imagine if we lost the sensors for the software managing the cobot should tell it to stop working or moving. All of these things need to have a way to be checked from time to time that the sensors or the cylinders that are moving the arms, all of the mechanics around the machine are working as we want to be*

> *sure that there is no degradation in the process that could affect the operators. We write down in the protocols and teach this protocol to the maintenance people and anyone taking care of the that and we need to keep records of the protocol as to decide what to do if we can still go on after the correction or would we need to stop immediately."*
>
> — P2M, Quality Director

Cobot safety from adoption viewpoint does not seem to deviate from a standard protocol where maintenance is required for all manufacturing equipment. However, safety concern extends beyond risks to the organization and includes acceptance from workers, for whom safety is of the utmost importance. Any concerns about safety can lead to criticism, backlash, and other negative consequences if inadequate safety measures are put in place and workers are harmed. Robot ethics expert P5R gives an example of cobot retaliation due to safety concern from the perspective of self-driving car,

> *"Can people trust a robot to sort of move safely and that's sort of a big area that comes up. There have been accidents involving driverless cars and cases where people have died. And again, you got people very fearful in relation to that. And we know this because in Arizona, which is where the first fatality occurs, when a company started to test their driverless cars there were protests against it like rocks being thrown at the driverless cars because people were very fearful about those."*
>
> — P5R, Robot Ethics Senior Researche

Hence, it is imperative that safety assessment is considered as a fundamental requirement from the standpoint of both cobot development and adoption. Proper safety assessments should be conducted at all stages of cobot development and implementation processes in order to ensure a safe, well-monitored, and standardized usage of Cobots. Although, it is a common practice for technology development as technology lawyer 11L mentions, *"if they intend to sell into the market,* *they're going to have to comply with all the product safety regime unless they are genuinely working with prototype, experimental mode. But to be able to commercialize something, you certainly demonstrate that you have applied to safety requirements whether it aren't specific and haven't been harmonized by the EU already, there are still general safety requirements."* The safety assessment is also required during the adoption process, as the Technology Public Policy Consultant, P4C, highlights*"how's supervision of the robots making sure that they're adequately done safety inspected before they're put into service?"*.

Furthermore, it is crucial to explain the safety assessment of Cobots to workers and cobot operators in a manner that is clear and easily understood. The very simple question like *"can the robot crush my hand?"*, as mentioned by P4C, is a common reaction that can cause hesitation and anxiety among workers which may undermine the adoption of Cobots if is not addressed properly. Therefore, as part of risk assessment, it is required that employees are comfortable with adopting the technology as manufacturing innovation expert P14M highlights, *"they would need to be confident again that this robot isn't going to knock them out with the left hook. I think with physical risk, we would need people to gain confidence that there isn't a guard around, how does this work as well as the health and safety side of it. How do health and safety managers manage the introduction of Cobots?"* This point is also reflected in The Acceptance Factors of Cobots section. Even if Cobots are proven to be safe, it is likely that safety concerns will persist, making effective change management and how the transition is being manage the key determinants of adoption success. In order to successfully introduce and use Cobots, it is necessary to shift the norm of skeptics and pessimistic perspective of cobot safety. However, this shift in norm cannot occur until the safety of the technology has been established and people feel confident in trusting it. Trust can be established at varying levels and types which is explored further in Section 3.3.10 section.

3.3.8.2 *Unless It's Safe, Cage It!*

Although safety is the minimum requirement, experts have not regarded Cobot safety to be apparent. Thus, the prevailing opinion from experts is to maintain the separation between robots and humans in order to ensure safety, albeit not ideal, it is the safest way to guarantee the safety of robots around humans. As mentioned in Section 3.3.2.3, the autonomous systems lawyer expert P11L emphasizes that the legal concerns surrounding Cobot adoption pertain to the ability to demonstrate safety. As a result, separating humans and robots is considered a simpler alternative. This approach treats Cobots in the same manner as traditional industrial robots which defeated the purpose of this emerging technology. Consequently, robotics and automation expert P15M views that there is a high interest in adopting Cobots in a form of autonomous trolley, however, it will depend on the task the robots will take on. The robots will need to work around human workers and having a clear path where the robots will operate because *"it is about this is where humans go, and this is where your items go. So it's about that segregation, try and make things safe,"* P15M highlights. Because at the level that it is determined for cobot to be 'safe enough' it is no longer functional so caging it to work at maximum capacity is the easiest and most efficient way P15 adds,

> *"But if you've got the robots that run on a normal speed, because of the unknowns and because of the distance that you'd have to work, you've seen how close our lines are and you see the amount of people that we have to fit on the line. If you actually had to use the right distances for speed and stop, we physically would have to double the size of the factory, so therefore it is not ideal. So the unknowns and the speed and the impact, it's a no go for us. Hence, we are continue to develop the concept of robot but it will be behind the cage."*
>
> — P15M, Robotics and Automation Expert

During the interview, P15M walked us through the manufacturing process and around the factory floor. This manufacturer is a major supplier for many of the commercial stores in the UK. The production process largely relies on human workers, aided by some machines, and the workspace between workers is relatively compact. There are Cobots in operation, but they are located at the end of the production line with a secured cage. Because establishing safety protocol for human-robot collaboration is challenging as the risk has to be as minimized as possible while the robot still has to be functional. From perspective of a lawyer P11L, the safety regime for robot is there, however, the guideline established the clear separation between human and robot;

> *"If you just have a box standard robot, they have robotic systems and the safety of work regulations. Interestingly, the mitigation for a lot of it is that there's basically separation between robot and human. The safety protocols or the terms of engagement is that risk is minimized at the lowest reasonably practical for the human. Safety as regards to the robot doesn't really matter. That's just the way the safety system is built, it's supported on risk of human life; damage to property is practically almost an entirely separate issue. So it's hard enough, probably just having a safety protocol in place where a human can work in the unsegregated vicinity of a robot."*
>
> — P11L, Director of Law and Connected Autonomous Vehicles

It seems that the primary concern with regards to Cobot safety from legal perspective is the prevention of any potential harm to the human workers in its close proximity. While there is a general expectation that Cobots are inherently safe when operating independently, the safety protocol requires special attention when humans are involved, even when the Cobots are enclosed within secured cages. However, from a design perspective, it is imperative to minimize the risks involved in human-cobot interaction while still allowing the technology to perform its intended functions effectively. Therefore, the need to demonstrate safety is paramount, as it determines whether the Cobots can be used safely and efficiently. The following debate is crucial to unpack on how safe is safe enough?

3.3.8.3 *But, How Safe is Safe Enough?*

It is important that the term "safe" is put under scrutiny. Experts raised concerns around the challenge of standard of "safe enough" for cobot development. From a commercial perspective technology adoption P9C recognises that *"there are a slightly different set of moral or ethical challenges and that is around when is the development of the product or a system complete? So, develop it forever and still not have it finished. But at some point, somebody has to say 'that is good enough.' And that's another challenge around what is actually good enough?"* Because the acceptable level is subjective and based on individual perceptions of risk and safety. We see that at the development stage, the issue of safety becomes more intricate in the context of human-robot collaboration since it is not solely dependent upon the safe and reliable performance of cobot's assigned tasks, but it must also account for the various interaction points between the cobot and human workers. Technology lawyer P11L highlights *"some of the most obvious safety concerns of humans interacting with technology when it comes to handing over specifically machine to human, a dynamic driving task, but it would also apply equally the other way I think then to when human would hand over to machine."* The safety assessment does not only concern how human workers will need to manage their collaboration with Cobots. Cobot developers need to consider point of safety Cobots to anticipate human worker's behavior because the interaction goes both ways. To test for safe human-robot interaction, it must first start with progressive safety testing of the robot against different use cases as senior lawyer P8L explains,

> *"There's an assumption that understandably people shouldn't get hurt and things shouldn't get damaged but you are then in a*

> *conundrum because unless you test them first, without testing them you don't know how safe it is going to be. So you do escalating test provision, as you test them you take out more and more of the safeguards, then you take out one of the protections, but you got to build up the use cases using testing until when people ready to take over. But you gotta have the consensus on what how safe is safe enough."*
>
> — P8L, Partner (Law firm)

Furthermore, safety is not just the mechanical side, but the data used in training the robot needs to be thoroughly considered to make it safe as the law and technology expert P7L raises, "You have machines that rely on voice recognition to get out of my way. But because I speak with an accent, it doesn't recognize quickly enough that there's someone then I get injured." In Section 3.3.3.4 P7L recognizes that responsibility gap and how to allocate liability is a problem, but safety is more worrisome from liability side as how to prove for product safety,

> *"What I think is slightly more problematic is to really say what are our benchmarks here? What are the baselines? If I use state of the art defence, and it is evidence that on average what I'm doing is safer than any way possible alternative. What exactly does this mean? How do we test this? How do we account for that? What type of evidence is permissible and needed to make that sort of claim? So, quite a bit of issues here on the legal liability side."*
>
> — P7L, Law and Technology Professor

Cobots are often promoted as being "safer" due to their operational characteristics and the associated benefits of utilizing these systems in the workplace e.g., improvements in worker safety and working conditions, owing to the assistance provided by Cobots in reducing the risk of repetitive motion injuries and other similar stress-related injuries. However, there needs to be a baseline to claim of safe whilst recognising that the degree of safety of Cobots is dependent on the specific technology being used and the associated risks that come with it. There cannot be a standardized "safe enough" threshold that applies to Cobots all across the board. Instead, specific safety standards and regulations should be created on a case-by-case basis, taking into account the specific context, environment, and intended use of each cobot system. The senior lawyer P8L who was a part of autonomous vehicles regulation consultation cited that *"we're recommending don't have a one side fit all but have different use cases because an autonomous robotic car is going 10 mile an hour is different risk profile to having 10 big trucks operating autonomously on a public road doing 70m/hr and each weight 30 tons."* This recommendation is highly applicable to Cobots a robotics arm and a trolley will require different use cases for safety assessment. Responsible Technology consultant P6C stresses that the assessment needs to *"focus on the specific aspects that you're trying to deal with, say 'this particular robot, in this context, in this scenario, in this point in time in the universe, it will work safely when these things happen."* Experts seem to suggest that there is a need to standardize the non-standardize safety assessment requirement, such that "one size fits all" risk assessments are not applicable. The standard practice should then focus on use case assessment to identify potential risks and hazards unique to a particular work environment and intended use of Cobots, to establish appropriate risk mitigation strategies that ensure the safe use of these systems. It is imperative that Cobots are used in a manner consistent with the identified use case, and any deviation from that use case would require a reassessment of associated risks and mitigation strategies.

All in all, prioritizing safety from the start of cobot development and adoption is critical to ensuring well-being of workers, building worker trust, and maximizing the benefits of cobot technology. However, safety standards need to be reflected the different use cases of Cobots. Cobots cannot be treated in the same manner as industrial robots where the safety standard only focuses on the mechanical safety of robots. Human-robot interaction introduces the new paradigm of safety. Thus, there needs to be established use cases for safety assessment to minimize the risk whilst still allows the technology to do its job. However, such requirement remains to be a challenge for cobot design which we will discuss in the next Section.

3.3.9 *Theme 8: Cobot Design Challenges*

Cobot design challenges are interconnected with previously discussed adoption challenges of this technology. Whilst Cobots hold tremendous potential for various benefits, the technology functions are still fairly limited, and they are a long way off from the speculative concept of "robot coworker." Perhaps, it is not required for Cobots to reach such stage but achieving certain level of human-robot collaboration still requires the resolution of numerous design challenges. Furthermore, it is recognised that the limitations of Cobots stems from the general development of the enabling technology advancement whether that be the physical mechanic parts that made Cobots (e.g., sensors and actuators) or the computation capability. It should also be highlighted that the challenges faced in Cobot design contribute to the ongoing discussion about whether the law could be a potential barrier to the adoption of this technology or the technology itself is still not entirely equipped, or at a desirable level, to be widely adopted by the industry. Unlike the law, the industry is still unable to reach technological advancement and the design challenges are hard limitation to Cobot adoption for its intended purposes. Consequently, robot ethics is an ongoing concern which equally reflects in the case of Cobots. Asimov's laws, though fictional, sparked an important debate on the role of robots and their place in the world. The science fiction highlighted our complicated relationships with the idea of robotics technology where we "remain constantly torn between the helpfulness of robots and the possibility of (primarily, but not exclusively, economic) disenfranchisement by them" (Geraci, 2007, p. 970). What and how should robots behave, should it be that the expected robot behaviors from Asimov's laws need to also reflect in Cobot design in particular when viewing from the future "robot coworker" perspective? In this discussion, we found that the design challenges are predominantly discussed from two different perspectives: technical challenges and concerns surrounding the design ethics. The former is explored in the context of Cobot technical limitation and expectations whilst the latter concerns robot ethics in Cobot design.

3.3.9.1 *Mental Dexterity: Cobots Can't "Think", at least yet*

As we have highlighted throughout this Chapter, the fear surrounding robots and AI taking over jobs requires some perspective. In the grand scheme of things, and particularly as explored in this thesis, we are still a long way from that becoming a reality due to the current technical limitations. Cobots are a relatively new concept, and although they continue to advance and become more complex, they can only operate within the confines of existing technology. The Deputy Director Robotics and Autonomous Systems, P1T, explained that to work with humans in a collaborative manner, Cobots are required to have certain level of dexterity, handling ability, and cognitive process for production line that are dealing with variety of materials. However, the current technical challenges and limitations still lie with the basic mechanic of robot as well as its programme. The expert highlighted that the challenges of Cobot in the case of human-robot collaboration deal greatly with the limitation of ability to adapt in the similar way to a human. Cobots will need to understand how humans work and anticipate the irregularity as the expert called it "mental dexterity" which is different to being dexterous to simply handling objects;

> *"There are going to be technology challenges in making robots that are dexterous and able to cognitively cope with things not being always the same time. It's a thing where there's more dexterity required and more ability to do the right thing when the*

> *situation is not exactly as it was the last time you did something - that kind of generalization adaptability that human beings have. It can't be a robot that always goes exactly the same point to pick up that part, which is true for a robot in a factory, it has to figure out that it's [the object] not there, it's over there, so it's in a slightly different place or is turned halfway round compared to where it is turn around by 57 degrees because the person might decide to assembly it in a different way now.* ***I would say that the degree to which a robot is appropriately dexterous such that it can be even capable to physically achieving tasks that would be expected to achieve in some kind of joint task with a human being or with other robots, we're a very long way away*** *because robots haven't been designed to meet those problems rightly prestigious. That mental dexterity and being able to cope with 1 in a 100 things going wrong and how should it be coped with, I don't know if we ever get to that point, at least not to the degree that human beings are now, maybe we will."*
>
> — P1T, Deputy Director Robotics and Autonomous Systems

Although P1T forecasted that the industry is still far away from achieving the point where cobots are capable of having "mental dexterity," physical dexterity is still yet to be solved. The innovation manager, P14M, viewed Cobots to be inflexible especially when dealing with mixed objects and adapting their actions to reach the same goal,

> *"A lot of the time it is the challenge of getting the material to them [robots], because we're working with materials which are products that aren't very homogenous. I think one of the things that the human does very well is, we're doing more than an A to B task. We're doing an evaluation of raw material equality. There's interaction of various systems, which is vision systems, weight control, and placement control. All of these things we do as human beings without thinking – for example, if you're*

> *making a sandwich at home, you're taking the amount of chicken for a chicken sandwich that you want and you're putting it on the slice of bread so that you get coverage of that piece of bread, so you get chicken in each bite. It's not always like that [with robot] because you've got different raw materials, different sizes, different shapes, different densities."*
>
> — P14M, Innovation Manager

Since the time of the Study, there are research projects on soft grip robots to help on the different sizes and density of object (Yumbla et al., 2022; Gabellieri et al., 2020; Tomo et al., 2018). Nonetheless, dexterity is one of factors required for human-robot collaboration. Similar to having "mental dexterity," machines cannot fully comprehend human behaviors or it is very difficult to program such capability. P11L, *"It doesn't matter I suppose whether you're talking about an industrial cobot or service cobot or task Cobots, like an autonomous driving vehicle. The idea that [one of those] might one day completely understand the intention, the planned actions of its human partner and anticipate those."* Robots do not have reasoning, at least not in the same way humans do. Logic in robots should not be viewed in the same manner as humans as the Chief Technologist Officer, P3T, explains "the risk and the level of supervision in terms of being able to empathize and understand the human point of view. If the human has done it before, then it might do but it's not going to understand why that human needs the screwdriver or why they should choose to make that gesture in order to request a screwdriver. It's only going to be able to surmise that from that having happened before and giving them the screwdriver make them happy." This concern needs to be made clear in Cobot adoption discussion. Although the technology holds a great potential to revolutionize manufacturing, these design problems that need to be resolved.

Our study has revealed that experts are not overly confident in human-robot collaboration or in robots supporting humans. In Chapter 2, we discussed the different levels of collaboration. At present, whilst it appears that cooperation between robots and humans is on the horizon, the capability necessary to allow for true collaboration is still far off. The collaboration requires Cobots to understand the different interaction dynamics which are viewed to be difficult. The senior lawyer P11L is skeptical, *"it gets even harder when you expect the robot and the human to work even more collaboratively, handing off to each other say repeatedly in the perceived fact and activity a task or a piece of manufacturing or whatever happens be. Present that you've got multiple points of engagement and disengagement of the human machine interface. And it's dynamic. There has to be some flexibility and adaptability of the old fleet, the system that exists between the human and the product, it's no longer an assembly line."* Furthermore, sensing feeling and social norms are intricately linked to the human condition, and while they can be programmed into robots, they are ultimately intangible qualities that cannot be replicated, at least not in the similar manner to humans. Although affective computing techniques are more adopted to help machines understand human expression, but such techniques still have limitations in emotion detection (McStay, 2020; Richardson, 2020). Despite adequate training of Cobots, Technology Adoption consultant, P9C, still believes that understanding humans is a key aspect that has been missing from Cobot development.

> *"What the machine of course can't generally do is learn a new thing, adapt to new thing, 'so this is what I did in this case, but so this is slightly different, but it applies like that.' So there is a definite limitation of people training machines. It strikes me that when a human is helping a human, example where that fella is doing something with the car and the human helping there perceives really rather a lot of information, don't they? Understands what it is that's required and then the understanding of how it feels when you start to screw this thing on. So there's a lot of sensory things in there. With all that stuff, a human helping a human would also perceive more of the lead humans attitudes, feelings. If I was helping the guy, and I knew what*

> *he was doing, or if he was stressed or tired, or all those sorts of things. So that would make a difference to how a human would help, and I'm guessing that* ***the robots would really struggle to find out and to have that richness of perception. You can train it where it needs to be, you can train it to turn and switch and push things in. But that sort of stuff is not nearly as rich as a human helping a human****."*
>
> — P9C, Technology Adoption consultant

Humans have ingrained mental models that we use to process information. However, despite the advancements in automation, integrating machine-driven processes into our everyday lives has proven to be a tricky endeavour, even for the simplest of tasks. When introducing Cobots into the equation, it is not enough to simply mechanize a few steps in the process. Rather, Cobots must be able to understand human behaviour and interaction, and that is often a difficult ask. As the Robot Ethics Senior Researcher, P5R, concludes,

> *"For the robot and the human together to be able to come to a point where they can interact smoothly and successfully, I think our technologies is still a very long way off that. If we think of the classic example of people interacting with the automatic checkout in supermarket. On any given day, if you're at those automatic checkers, there's somebody there who's getting really, really frustrated at the checkouts because they're frustrating at things that interact with them. And sometimes it's because they have an unexpected item in the bagging area. And often times, because it's asking him questions are kind of out of sync with the process that humans would interact with each other, and so on. And that kind of frustration when interactions break down, actually, they can have a big effect on how people can achieve tasks. So you need to have something that is able to interact in quite a sophisticated way to be able to ensure that smooth interactions take place."*
>
> — P5R, Robot Ethics Senior Researcher

Without a technological breakthrough, it may be unlikely that Cobots will be able to interact with humans in an effective manner. The complexity of predicting and comprehending human behaviour may remain a major limitation in the development and adoption of Cobots. Furthermore, experts found that it is difficult to guarantee safety whilst meeting functional requirements if cobots operate similarly to human workers. As Innovation manager, P14M, explains,

> *"And the challenge again, that we've had around the Cobots is just the speed of movement and being able to either match or surpass the speed that a human can operate a task on a production line. Too slow. If you imagine if making sandwiches, for instance, when you've got someone picking up chicken and putting it on the sandwich, they're doing a few operations – one, they are making sure that they're getting enough whole pieces of chicken, the right weight of chicken because they're working off what we call negative weigh scales, and then they position it on the actual sandwich. So that operation will take maybe four to six seconds. And to get a cobot to do that and move to the physical movement in that time. There's a challenge. It almost pushes us back the other way as in when we can use robotics that can move at higher speed. How do we overcome the sacrifice in terms of guarding, etc, that is needed and trying to figure that out?"*
>
> — P14M, Innovation Manager

The mismatch between human and robot capabilities could imply that achieving successful human-robot collaboration will be highly challenging. The design challenges are pointed out from making comparisons between designing cobots to be like what humans are capable of, but perhaps replicating humans are not the key. Rather than trying to mechanise humans, it may require a new way of thinking to match up human and machine capabilities. Without a technological breakthrough, it is unlikely that Cobots will be able to interact with humans in an effective manner. The complexity of predicting and comprehending human behaviour is a major limitation in the development and adoption of Cobots.

3.3.9.2 *Design Ethical Robot vs Design Robot Ethically*

Robots and ethics have become one of the prominent discussions especially from the perspective of responsible robotics (Urquhart et al., 2019). The adoption of Cobots certainly sparked the conversation around how technology should be developed with ethics in mind. Our interview experts touched upon this subject from 2 distinct perspectives: the challenges of designing ethical robots and how robots should be ethically designed. These perspectives are from different approaches with the former being the implementation of ethics into robots whilst the latter concerns the ethics around how Cobots should be designed and developed.

Our interviewed experts found designing ethical robots to be a challenging goal given that teaching a robot to make ethical judgement is just difficult as humans still do not have it figured out. The senior lawyer working with autonomous systems P11L pointed out the very common critique with self-driving car and the trolley problem (Nyholm and Smids, 2016; Bonnefon et al., 2015).

> *"Within automated driving, this is pretty much a recurring joke that at some point, you'll get someone's throwing in the trolley dilemma, which is the most far-fetched and ridiculous concept. You know, it's doubtful that over 60 to 80 years worth of human driving that any single human has ever faced such a dilemma, and that's no matter what they chose they could be ethically blamed for either choice. It is the definition of the most pointless question that was repeatedly asked at all times."*
>
> — P11L, Director of Law and Connected Autonomous Vehicles

The trolley problem, a classic topic on the ability of machines to make ethical choices, has long been explored by many (Karnouskos, 2018; Coca-Vila, 2018; Wolkenstein, 2018). Whilst it is a noteworthy debate, it may be possible to argue that placing such ethical test to a robot is not realistic given that even for humans the approach and answer to such moral question is still polarised (Bauman et al., 2014; Königs, 2023; Frison et al., 2016). Because depending on the school of thought, variety of scenarios may form to morally justify a decision (Thomson, 1984; Frison et al., 2016). Technology expert, P3T, remarked that in general robots do not perceive and comprehend reasoning the same way humans do. Although there are different moral beliefs, humans have certain moral compass or capacity for cognitive reasoning that guide our decisions as opposed to making decision solely based on data received information. In some cases, it may be easier for robots to operate such as in production line of controlled environment. However, the more dynamic the environment becomes the difficult it will be for Cobots to operate it. As P3T explained,

> *"[Robots] are going to be rationalizing that data experience down to heuristics which is the way the whole of AI works, heuristic and correlations. If I make judgments and assumptions about people, which quite naturally, that is a mental performance hack. My brain does it and it could be inaccurate. But I've got a moral belief system that balances that out. We are decades away from building a moral belief system in robotics. We are now able to put these robots into controlled environments, but the difficulty comes when they become functioning enough for us to put them into a wider environment but we haven't yet got the technology to build in that moral counterbalance that humans have when they use heuristics or rules of thumb."*
>
> — P3T, Chief Technologist Officer

Perhaps we are being too critical about robots making ethical choice and using that as a benchmark for robot adoption. Perhaps it should not be used as a benchmark or point of argument of why technology is bad. The debate should instead focus more on other ethical design factors for robots, such as ensuring the safety and privacy of individuals, rather than if a robot can make an ethical judgement. At the end of the day, it is the programmers who will make the decisions for the robots so the focus of making ethical choices should be directed towards designer of robots.

From the adoption point, it is just as important to ensure that Cobots are designed and developed with ethics in mind. However, interview experts observed that there is not enough awareness around design ethics amongst technology developers as the Responsible Consultant, P6C, highlights

> *"They're not taught above that, or historically they have not been taught ethics or anything about social responsibility, they taught the technical side of it. So until that happens, it's going to be a current profit bottom line mitigation activity with marginal safety perspective looking at a very limited group of stakeholders, because currently, systems engineers are not taught how to reach out and engage with stakeholders and until they do that, then they're not going to understand what the real issues are. it's not part of the overall organizational mandate to do that unless executive management is aware of the need to do that."*
>
> — P6C, Responsible Technology consultant

The discussion from the perspective of design ethics ties closely to the role of law to drive responsible Cobot development and adoption. It highlights a limitation of the role of law considering that regulation places responsibility on technology providers though companies tend to only do the minimum necessity to comply with the law providing the cost factor, as we have discussed in Section 3.3.2.3, which does not quite deliver the same objective as design ethics. Design ethics put people first whilst legal compliance is motivated by financial risk. Therefore, this may require a change in culture and education to help embedding design ethics into technical development. As interviewed experts found that there is currently a lack of human factor in design by expecting the operator to be perfect without considering differences of users.

It should also be pointed out that a question of ethics and how its meaning is perceived by different experts is an interesting one, but one which we will not be exploring in this thesis. In the Study, we observed that following the section above on mental dexterity of Cobots, the discussion on ethics is important, however, this is not uniquely to Cobots. Rather, this challenge applies to all robotics and autonomous systems development. Embedding ethics in machine is not a new subject, yet, it still has not been hacked. There has been more progress in implementing ethical considerations in systems, such as the development of ethical frameworks and guidelines, to ensure that autonomous systems are trustworthy and aligned with human values[8]. Considering this research sector is still developing, it is understandable that ethics will be a prominent issue that comes up as the core of adopting Cobots. Consequently, it is important to consider the limitations of robots in terms of their ability to make ethically sound judgements. Knowing the limitations of robots can help us better decide the roles they the job they can and cannot do, or rather, should or should not take on, potentially preventing dangerous or unethical outcomes.

3.3.9.3 *The Needs for User Centric Design and Inclusion of Cobot*

As design challenges are Cobots adoption barriers, experts considered ways in which Cobot developers need to prioritize. Throughout the Study, the design of Cobots is strongly linked to the perception of robot safety which, in turn, reflects the level of Cobot acceptance and adoption level. The interviewed experts recognize that managing safety risks can help employees feel more comfortable adopting new digital manufacturing technologies and therefore Cobot design with safety as priority needs to be unpacked further. Because technologies like Cobots receive much skepticism. Accidents involving robots are regularly reported in the mass media, further increasing the safety

8 such as the work led by the UKRI Trustworthy Autonomous Systems Hub https://tas.ac.uk/

concerns people might have (Associated Press in Berlin, 2015; Clarke-Billings, 2017). According to Technology Public Policy Consultant, P4C, people often question whether robots can injure them. Employees are concerned whether the robots are adequately inspected for safety before being put into service, as noted by the innovation manager, P14M *"I think they would need to be confident that this robot isn't going to knock them out with a left hook."* The Robot Ethics Senior Researcher, P5R, shares a similar viewpoint: *"safety is a huge component of trust. If you don't feel that a robot is safe, you're very unlikely to trust it when you're interacting with it".*

Ironically, although safety is to be one of the major factors that should dictate the design of Cobots as safety contributes to employees' acceptance and trust, experts raise a very important issue on the lack of inclusion of different stakeholders, particularly the end users in design and adoption process. The Responsible Technology consultant P6C highlights *"And that's where the stakeholders have to come into it because one, it's been proven that developers cannot possibly understand or predict how it can be used, how it can be misused, how the harms can manifest without actually going out and either getting feedback directly from stakeholders in the field or they're part of the design process or participated design."* However, such inclusion is not being practiced enough by industry even though it is required. In the UK, in light of Sentencing Council (2015), companies can face up to £10 million fine due to breaches of health and safety law if falling short of appropriate standard which includes ignoring concerns raised by employees or others. Manufacturers, as Cobot adopter, need to consider having a formal process or procedure to provide employees with a platform to voice their opinions and concerns throughout the design and adoption process of Cobots. Without allowing employees to speak up, it coul be then argued that the concerns they might have were ignored. With such oversight, in turn, would still lead to unsafe or inadequate safety levels of Cobots, resulting in breaches of health and safety laws, as companies would have failed to put in place appropriate measures to ensure a safe workplace environment.

Furthermore, according to the Law and Technology Professor P7L, there is the tendency to use technology that works sufficiently well and then expect humans to adapt their behaviour. Although this might work for the 'average' person, it might pose problems for people who have been marginalized in the dataset used for training and design. The expert continues with an example of voice recognition that enables Cobots to interact with people; the lawyer sees that there is a risk that it will not understand a wide range of people, such as those who have a strong foreign accent, speakers with a regional dialect, or people who speak minority languages such as Gaelic or Welsh. We observe that this could also lead to in-direct discrimination in hiring if the robot only works efficiently and safely with some groups of people, as businesses may exclude certain groups of applicants with the justifications on grounds of safety.

So, how do we design Cobots to work with all stakeholders? inclusion in design ethics requires that Cobots are trained with a wide range of data to ensure that they can interact with a variety of stakeholders. Fundamentally, it is important to recognize that Cobots are only as good as the data that is used to train them. The senior lawyer P11L raises this concern,

> *"There's quite a lot of unpredictable consequences of that, depending on what data that you use. For example, there are lots of trials going on about how an autonomous vehicle might be able to predict that someone is about a step under the road, possibly less of an issue in places where jaywalking is a crime, but certainly in the UK you can cross wherever you like, and people do. Some people do not pay attention when they do so increasingly they're looking at their phones sometimes. But how do you train a car to anticipate that someone might do something which is frankly, a bit unpredictable? Possibly also a little bit irrational? Yeah, very, very difficult. I know people who consider game the-*

> *ory and psychologists to [help train] and kind of pure data scientists. Everyone knows if you just feed it a data set, they can draw wrong conclusions. For data set, for example, just happened to contain a lot of people who are wearing red stepping out and in rarity you can only draw conclusions that people wearing red will step out into the road, which is not quite right.* ***Humans can understand the difference, but algorithms cannot. Because humans are just incredibly difficult to read. And we're still trying to train AI to read humans.***"
>
> — P11L, Director of Law and Connected Autonomous Vehicles

Consequently, training data also reflect real world social setting where it is possible for bias to be replicated in digital technologies. Responsible Technology consultant P6C emphasizes on the quality of training data,

> *"Because when we process bias in our human brains, we do it differently than a machine will do and the outcomes will be different. If you're in a crowded room, even though you're inclined, you may not yell out a racist comment because of the other constraints in the room and other people. With machines, we don't have that capability yet to draw in all of those variables that should influence how the machine is learning and what it's learning about. That's why you get Google recognizing black people as gorillas. That's where it reflects back on that whole process of 'do you have the right inputs?' because that same adage that's been historically true for all of my whole career in systems engineering. Garbage in garbage out still will hold true here. The garbage in in terms of bias data, the mistaken assumptions, etc, they're all going to point to those problems downstream that if you pay attention to them, you can prevent them from happening."*
>
> — P6C, Responsible Technology consultant

Although this point will need to be considered from the perspective of data protection as often Cobots are trained on available data as opposed to desirable data sets, thus neglecting of data inclusion can easily happen (El Zaatari et al., 2019). To truly embrace inclusion within design ethics, Cobots must be trained with data that is diverse and representative of the many different communities and stakeholders. Furthermore, following the section above on design ethics versus ethical robots, it is essential that we pay close attention to the nuances of ethical implications of the design and the development of autonomous systems. As such, the unintentional bias could stem from a sheer ignorance of the designers, therefore, before we think about robots making ethical decision, we need to start with the design ethics principles to help highlight and guide design of Cobots. Interviewed experts raised these concerns given the lack of awareness surrounding inclusion in design. The Chief Technologist Officer, P3T, sees this challenge as a call to break the long-standing self-serving bias and the need to focus on the end users.

> *"A big issue with algorithms is hidden inferred variables that aren't explicitly fed into the algorithm but influencing it. When you are talking about reinforcement learning, that also has implications A lot of our technology that we use today was designed by five white guys in a shed in San Francisco, right? This is just self - serving confirmation bias. We all need to be aware of it and try to avoid it... Have you considered all the types of users that are going to interact with the cobot? So that design process and the governance around that design process so again, analyzing your stakeholders and your users, analyzing the risks, and analyzing how those risks could manifest in your system and then mitigating those things through design or evaluation are really, really important."*
>
> — P3T, Chief Technologist Officer

The ethics in design principles is a building block towards Designer Due Diligence. The need to ensure safety arises from adoption concerns which reflects the factors of what makes a Cobot safe from the perspectives of its interaction with human workers and the environments. Therefore, Cobot design needs to put end-users at the core as lack of understanding of the end users can lead to significant safety risks in the implementation. People tend to have higher standards and unrealistic demands towards robots and other autonomous systems. When researchers tested individuals' tolerance for mistakes made by artificial intelligence software, they found that people demand a much higher success rate from robots than from humans (Prahl and Van Swol, 2017). This can lead to safety problems as people may become less vigilant when interacting with autonomous systems because they expect them to make no errors; whereas technology designers place their expectation on the operator to ensure that the system performs as it should. These are expectations that operators cannot satisfy. The senior lawyer, P11L, states, *"The technology being designed almost under the expectation of humans cannot fail, which is completely wrong. We see accidents where one of the emerging issues appears to be a fundamental misunderstanding of the technology."* P11L emphasizes that risk manifests itself when either the limits of technologies are clear but not communicated properly or when the limits are unclear or not understood. Product safety is the minimum requirement for technology adoption. However, in the case of collaborative robotics, there is an additional layer of complexity as the technology is designed to be adaptive to work with or alongside human workers. Having inadequate understanding of the end users can result in serious consequences. Hence, inclusion of different groups of end users in design and adoption is key to ensure safety of the employees when interacting with robots.

Moreover, humans in the loop should be formed as part of design ethics in the context that humans will always have the authority to review and override the autonomous systems. In the case from legal perspective, it can be viewed that technology operator should or is responsible for the results and actions of the autonomous systems.

This point can help to simplify the liability process as well as ensuring technology acceptance given that people appreciate the use of autonomous systems if it can still be override when necessary. As technology consultants P6C and P10C view it,

> *"Getting to the levels of where autonomous decision making is ok but never allowing true autonomy is really where the world needs to go because we can automate anything, but we cannot give away autonomy. Because if you think about even in that situation with the airline pilot, the plane itself is not truly autonomous as long as the pilot can disengage it, and that's what we need to make sure is in place. Basically, even in a situation where the pilot is giving full control to the plane, the pilot still maintains control."*
>
> — P6C, Responsible Technology Consultant

> *"There needs to be understanding on both sides of that, collaborative arrangement or transaction, about the limits towards that goal, your role and my role, what each of us brings to the party. That means there should be some rules and transgressions and fixity around software or what it can and can't do without permission or without some sort of override."*
>
> — P10C, Technology Implementation Consultant

The concern reflects the acceptance and design requirement for Cobots. From design ethics standpoint in consideration to humans in the loop principle, fully autonomous systems are still not quite the desirable function as a senior lawyer explains,

> *"At that level, they will actually prevent humans from overriding and taking control. That seems to be quite a big, emotional and psychological barrier for people. They like the idea of assistance, they love the idea that they might be able to pass the boring part of a drive on to a system. They hate the idea that they might not be able to retake control even where you can make strong arguments that is for their own safety. The feeling of being out of*

> *control or not being a contributing part of a task fills them with dread."*
>
> — P11L, Director of Law and Connected Autonomous Vehicles

It is a difficult dilemma for Cobot designer: how to ensure the robot follows the fixed agenda set out by the designers to prevent any malicious intent or incorrect usage whilst also allowing the operator to take control when required? This presents a major question of how to effectively design an autonomous system with an appropriate override function for operators that can be used to rectify errors that the robot may have missed without risking the safety integrity of Cobots. All things considered, there needs to be a priority that humans should not be adapting to the robot way of work, but rather the robot adapting to working with humans whilst still maintaining its technological superiority. The Study demonstrates that inclusivity in robot design and development in respective to ensuring accessibility to all users with different abilities and needs is essential to HRI system, however, this is yet to be reflected as necessity in a wider HRI community (Apraiz et al., 2023). Therefore, machine limitations must be overcome, but equally the reconsideration of process and how Cobots should work with humans need to be redefined. The collaboration approach will need to be reconfigured to unlock the full potential of cobots and harness the power of technology in a safe, user-centric way.

3.3.10 *Theme 9: Trust*

Trust is one of the key topics for technology acceptance and particular the uptake of robotics (Holder et al., 2016). However, it is a complicated subject in a workplace setting as we have discussed in Section 2.4.4. This section looks at various types and levels of trust. The perspectives of challenges in gain trust in Cobots are varied ranging from the perspective of trust in the actual technology to trust in technology driven by the purpose of its implementation. Trust in the machine or technical aspects of Cobots stem from the perception towards safety physically, digitally (data), and mentally in which we have discussed extensively in Theme 7 safety (Section 3.3.8) and Theme 8 Cobot Design Challenges (Section 3.3.9). Therefore, in exploring the specific challenges of trust in Cobot adoption, the findings are presented from two different angles: 1. Trust in a specific context of human interaction with autonomous systems and 2. Trust as a socially constructed concept and its significance in the workplace.

3.3.10.1 *Trust in Human-Robot Collaboration*

In this first discussion, experts are of the opinion that human-robot collaboration requires trust at a level similar to how one would interact with their colleagues. Deputy director in robots P1T states, *"That team has to trust each other, or I should say that humans have to trust the robots. There's some closer degree of collaborative work where there's a significant element of trust in or from the human."* P12L also agrees, *"I think it is about trust, and personally I think a lot of good in the workplaces is based on trust and how you make assessments about people. From a human perspective it's probably going to be harder to make assessments about robotics in the workplace if you've not been given the information about what it is that they're doing, and the information that they're collecting."* P2M adds that human employees work well together because they communicate with each other, and such interaction will be required between human and robots. On that ground, P5R highlights that transparency and explainability need to be the key elements in design to build trust, *"people can't trust something if they don't know how it works. And that creates a difficulty because a lot of the time with this very complex AI stuff we don't know how the decisions are made."* The expert poses the following questions: *"Should we try to create tools that are explainable to people? And if we can't explain them, should we be using them? I think that's kind of a question that comes up with automated decision making. So* *transparency is a big issue in relation to trust."* This is the same argument mentioned by P3T:

> *"Another aspect to this is 'explainability.' Let's take a health care robot, a cobot is collaborating with a senior citizen to make them move around or take their medication. Imagine that you are that person, you are alone with that robot and it does something that you don't understand or expect. There is a very strong argument that in order for people to trust these kinds of robots, there needs to be a way to understand why it did what it just did."*
>
> — P3T, Chief Technologist Officer

The issue of liability is now even more important, as it deals with people trusting in technology. This is a chain of events; for people to trust the robot, they need to be confident that someone can be held accountable for any damages caused by the robot. Liability is difficult to determine when dealing with autonomous systems, and this is recognized to be a problem. It is essential to consider the implications of liability when developing autonomous systems, as this will ensure people have trust in the technology and its ability to operate safely and responsively.

Nonetheless, P1T argues that it is important to build the right level of 'trust' to prevent over-trusting, *"there are some situations in which humans have a tendency to trust machines when they perhaps shouldn't."* This is an interesting argument as other experts suggest that to earn the trust of people, robots need to possess a certain level of understanding and communication. Unfortunately, this poses a design challenge that robots currently have difficulty in overcoming. This discussion indicates that the limitations of technology development, rather than the law, are the roadblock to people trusting and utilizing robots on a widespread basis. Therefore, it appears that the current design challenge will need to be addressed in order for robots to become more widely accepted.

3.3.10.2 *Trust in the Workplace*

Trust in the workplace plays out differently to the general perception towards Cobot adoption. Interviewed experts found that trust in the case of human-robot collaboration in the workplace is more so about knowing the technology is there to help rather that the physical safety. In other words, to define the term 'trust' and whether people choose to trust the robot or any piece of technology, it should be acknowledged that the purpose of the implementation technology will also be weighted in as much as, if not more than the actual attributes of the technology (e.g., design, safety, etc). As such, trust in technology is based not only on the features and capabilities of the technology itself, but also on the purpose for which it is being used. When asked the senior technology and data protection lawyer, P12L, if they think that trust relies on the notion of knowing that the technology is safe. The expert answered *"I think so but I don't think that would be so much of an issue. I think it will be more around people's perception about what they're there to do as opposed to anything of physical impact."*

The senior lawyer P8L also found that, besides the safety element, how people perceived the purpose and the benefits of the technology adoption will highly influence their level of trust.

> *"One is it is the willingness to make that choice confidently that it won't harm them. It is only matter where the individual has a choice or society has the choice. Because he or she will block it unless there is acceptance or confidence that the benefit will outweigh the downside. I think this is where I define trust. And second element is attribution of motive to those carrying out the activity. Let say we can have 2 identical AI application, medical application, it's a surgical robot. Same surgical robot, what is the level of trust if that is being to operated by a private medical company looking to take the NHS private versus it is being introduced by the national health service. Same bit of kit, same use, same place, what is the differential of trust? It is about the attribution of subjective motive to person introducing it."*

— P8L, Partner (Law firm)

Nevertheless, the discussion around trust may be irrelevant in the context of Cobot adoption. It can be argued that only acceptance, and not trust, can be achieved in the workplace. The senior lawyer, P8L, made a profound remark following the statement above on the essence of trust.

> *"Trust is only relevant to discretionary action, isn't it? Because if I am being told by my employer 'this the way the factory is going to operate', I have two choices: to leave or to accept it. I might not trust it at all, but my only choice is to stay or go. It isn't to work with it or not work with it. It's also about power structure because if corporations have the ability to bring [robots] in, it might not matter whether the people accept it, trust it, or want it. Frankly, if they are in the lesser bargaining position economically, those resistant factors are less relevant and that is not a social or political comment, it is just a fact, reality."*
>
> — P8L, Partner (Law firm)

The robot ethics researcher, P5R also noted a similar argument,

> *"In order to trust something, you have to have a choice of whether to use it or not. If we're kind of talking about robots in the workplace, trust is only relevant if it's a choice to have those robots there or not. If they're kind of enforced on people, then they just have to rely on them as being safe. If people have no choice, whether or not they trust them is kind of irrelevant in that sense."*
>
> — P5R, Robot Ethics Senior Researcher

It can be concluded that trust is a complex and delicate matter. Striking the balance between building trust and preventing over-trusting in technology needs to be achieved in the understanding the interplay between safety, design, and humans-in-the-loop principles. Consequently, the discussion on the dynamic relationship between trust and acceptance still needs to be unpacked despite the controversial findings on the irrelevance of trust in the workplace.

3.3.11 *Theme 10: Ethical and Social Implications of Cobot adoption*

This section mainly presents the impact of the introduction of digital manufacturing technologies in the workplace providing that ethical concerns regarding technology design and trust are already covered in previous sections. We found that the ethical challenge posed by Cobots is distinct from that of other autonomous systems counterparts, such as self-driving cars. Although, Cobots do not face the same ethical dilemmas of the trolley problem, the ethical challenges are more prominent on the impact of the use of the technology as opposed to the actual design of the technology itself. In this section, rather than focusing on the ethical quandaries of autonomous systems making decisions, we are instead focusing on the impact of the use of Cobots on the workforce and the route forward to sustainable Cobot adoption.

3.3.11.1 *Ethics is Contextual*

Before we embark on the discussion on the ethical and social implications of Cobot adoption, it is prudent to explore what ethics mean particularly from the perspective of technology adoption. It is not within the scope of this PhD thesis to explore ethics in technology adoption from a philosophical point of view [9]. Though within the Study, we are able to capture the perspectives of industry experts in order to gain a better insight into the topic. What has emerged is a fascinating range of opinions, all of which contribute to our understanding of the complexities of aligning expectations and standards with regards to ethical Cobot adoption and the need for greater transparency and dialogue between stakeholders. Ethics in Cobot adoption is contextual. We found the findings to echo the objective of this PhD thesis which

9 See (Vallor, 2016)

is the need to bring together different perspectives from various disciplines in order to provide a comprehensive view of Cobot adoption and to provide insight into this multi-faceted issue.

To enable stakeholders to discuss the future ethical implications of Cobot adoption, understanding the complexity and potential different in interpretation of ethics will play a big role. The enabling stakeholders to discuss the ethical implications of Cobot adoption. The Responsible Technology consultant, P6C, explains what ethics means in their opinion and,

> *"if you look up a dictionary definition, it's the moral or philosophy of the day. In my opinion, ethics is a contextual analysis, examination and decision that says that you're not going to harm. It's always contextual and it always has a set of boundaries beyond which you can't say things are ethical. So each, it's a contextual moral decision. I haven't even seen a consistent definition on ethics. Nobody's even willing to try to define ethics yet."*
>
> — P6C, Responsible Technology Consultant

A similar perspective is also shared by a senior lawyer,

> *"Ethics is contextual. And if I am to talk about a highly automated sports car, say Ferrari decided to create an autonomous Ferrari. And at the other end, a small manufacturer decided to create an autonomous vehicle, which was designed to help the elderly and those who are unable to move around freely to mobility needs. I would very much predict that questions of ethics vary depending on whether you're asking a question in respect to this Ferrari or what might be called as mobility aid. And for Cobot, to the extent that you know, robots maybe use to assist those who need assistance. You may well find that questions about ethics different substantially even those who were using them for high end manufacturing. It's very difficult to say so. But ethics wise, there's almost no point talking about ethics and*

in a vacuum or in a bubble. It's even worse, I think, to assume that is a right answer."

— P11L, Director of Law and Connected Autonomous Vehicles

How ethics is viewed is highly influenced by the context of technology adoption. Thus, the considerations for ethical implications need to be discussed through the perspective of specific use case. We also see the point on the being context specific in Section 3.3.8.3. In the opinion of experts, generalization appears to be a nebulous concept with regard to Cobot adoption. Whilst we observe the common opinions towards harmonizing Cobot regulation in Section 3.3.3.3, safety concerns and ethical considerations are notably context dependent.

Furthermore, technology itself remains impartial, as identical technological systems can have varying ethical and social implications depending on their intended use and design. This emphasizes the significance of contextual factors in shaping the understanding of Cobot adoption challenges as the ethical considerations concerning the technology need to be framed in a specific context. In other words, the framing of ethics of the technology at question should be explored from the context of purpose of adoption and who gains from its exploitation as the Responsible Technology consultant, P6C, explains.

*"In terms of social responsibility, I think **it all depends on the organization because again, technology in itself can be benign, or it can be used as a weapon.** I think it goes to the organizational culture and what the shareholders and/or stakeholders want from that organization, because they can choose to augment the workplace with robotics, or they can choose to supplant all human activity with robotics. So then it really becomes, what are they intending to do? So, again, it's like any technology is neutral. It's how you use it. If you're moving employees out of a job space, retrain them and put them into something else. Once the decision has been made to use robotics, then what? And that becomes then the risk assessment and the social*

> *responsibility start to kick in to say* ***'do we care about human rights? Do we care about employees that we're replacing have been with us for 30 years?' Those are the kinds of implications of technology people don't want to think about because I'm just the business. I'm only here to make profit.*** *I mean, car companies do long time, layoffs employees whenever it's downturn, or just take their whole facility out of town and move it somewhere else with cheaper, is that responsible?"*
>
> — P6C, Responsible Technology Consultant

The senior lawyer, P11L, also believes that *"ethics is really, really, connected to public acceptance and societal expectation."* Although, it is a well-known phenomenon that discussions around the topic of ethics are closely related to the social implications as it is impossible to have a meaningful discourse on ethics without considering the public perception of the matter. However, whilst engagement with the wider stakeholder community in Cobot design and adoption is a necessity, we see this argument throughout the Study that rigorous resource allocation for such activities is viewed as financial burden.

> *"It becomes a part of the broader discussion in terms of if you're trying to be socially responsible, and you want to use robotics, that's fine if you consider the implications of doing so. And if you've looked at the environment, the social and the financial implications of everything that you're touching, including your customers, maybe you can navigate a good path that doesn't hurt anybody. And that's why it's so hard for people because they have to examine everything that they're doing."*
>
> — P6C, Responsible Technology Consultant

Furthermore, when it comes to ethical and social ramifications, the impact on the workforce remains at the forefront of the discourse, albeit embroiled in controversial opinions as mentioned by P3T, *"So for the societal concerns perspective, obviously, job losses are always going to be a concern. I don't know if I'd qualify that as ethical but that probably* *depends on your political viewpoint."* We experienced a similar conversation during COVID-19 pandemic We see this with the pandemic too – economy vs public health? but what is the ethical decision? Choosing public health while the economy is tanking, which will result in layoffs anyway. Same with technology, if company cannot keep up with industry and market – bankruptcy still results in layoffs. If we do not innovate and improve, business will stall. We need to think long term not just the immediate effect that we can see. However, the discourse on this issue may benefit from the insights of experts in other fields such as philosophy and economics - which may be beyond the scope of this PhD thesis.

The ethical implications of Cobot adoption are multifaceted. We have established that any ethical concern with respect to DMTs and Cobot adoption ought to be viewed within its particular scope rather than being treated as a universal concept due to their context-dependent implications. Therefore, as ethical considerations are contextual, the following discussions will concentrate on addressing the very concern of potential job displacement due to technology and the implications of digital manufacturing technologies including Cobots.

3.3.11.2 *Addressing Job Displacement Debate*

The introduction of technology inevitably leads to the fear of job loss. Although the innovation manager P14M's experience with technology implementation is rather positive, "We have got various systems and operations automated with robots; people tend to take those quite well," robot ethics researcher P5R found that a heightened fear around robots taking over people's job is the first concern people bring up, worried that automation will remove the need for humans. This is also reflected in the opinions of the surveyed manufacturing employees, with 72% of the participants agreeing with the statement that robots and other digital manufacturing technologies will replace unskilled workers. Furthermore, all respondents agreed that the job security for people working directly with newly introduced digital manufacturing technologies has decreased (mean decrease of 3.33 (20.49), t (154) = -2.02, p = 0.045). Interestingly, the shop floor workers feel this less strongly than the managerial group (shop floor mean decrease 1.04 (21.02) and managerial role employees indicated a decrease of 6.03 (19.65), although the difference in opinion of these two roles only approached significance (U = 2475.50, p = 0.068). Technological unemployment is a pressing issue as research has shown that the implementation of certain digital manufacturing technologies may result in a decreased number of low-skilled workers because it only requires few skilled workers to maintain the machines (Graetz and Michaels, 2018; Lima et al., 2021). Experts also highlight that the danger of job displacement may not only apply to unskilled labourers. Technology adoption consultant P9C argues, *"A skilled craftsman that teaches machines how to replicate work is effectively doing himself out of a job or perhaps not getting the full value of that skill and experience."*

Arguably, workforce inclusion and sustainability could be in jeopardy depending on the approach taken by manufacturers introducing technology into the production line. As highlighted in Section 3.3.2.3 where in many cases firms are likely to uptake full automation as opposed to human-robot collaboration due to cost and safety reasons, Senior lawyer P11L argues that it is more likely that companies will choose automation over human-robot collaboration because it is legally easier to demonstrate that a safe system of work is in place when there is a clear separation of workers and robots. Robotics and Automation Expert P15M also recognises the complexity in incorporating new technologies into the workplace to do tasks currently performed by human workers. The expert advises that organisations should not design technology to do the same task in the same way as people are doing them. Instead, organisations should redesign the process completely and only consider technology capability to reach the desired outcome.

> *"Go back and look at the process as in, 'what are you starting with? What is your driving end result? Look at those individual*

> *activities that we currently do that you might not need to do [. . .] You need to understand the difference in what you achieve via a human versus what you can achieve by a process [. . .] if you mechanize the wrong human, you've created more issues."*
>
> — P15M, Robotics and Automation Expert

However, P15M only speaks for machines performing existing tasks, not explicitly implying that human roles are fully eliminated or will be replaced by machine for future tasks. In some tasks, it may be that full automation is more efficient and safer, but opportunities where humans and machines can operate effectively together should also be considered.

3.3.11.3 *Changes in the Nature of Work*

However, **the focus should also be about how the job is going to change** rather than being replace and how can we support the change?

> *"So I would say really the ethical concern I have here, is the return of modern times in many, many more professions, including the legal profession, possibly trying to keep up with the speed of the machine, not being able to step back to say, 'I need a little bit of time to think that through, I want to talk with another human about that', being forced to make decisions much, much more rapidly without consultation, I think that in particular a challenge also for legal profession and possibly medicine, when you think about cobots, most professions that you say 'it's part of my job to do things right and I take my time that I'm in charge here, that I'm not just following orders.' Surgeons are given a lot of power because of the training to make these types of judgment calls, and that is taken away and it becomes more mechanistic.* ***I think there are broader ethical and social concerns here. Not about 'will we have job' and lots of people worried about that. But what is really that quality of that job going to be?*** *And that's simply the quality of*

> *the work experience. And that's not a new fear either [10]. If you go back to Charlie Chaplin modern times, the human who is the slave to the machine has to work faster and faster and faster, to keep up with the production line. That was a big concern when we introduced automation in the workplace."*
>
> — P7L, Law and Technology Professor

Although DMTs will changing conditions of manufacturing work, our survey showed that there are many benefits of implementing new digital manufacturing technologies for the employees working directly with these newly introduced technologies. Clear benefits are, for instance, a significant decrease in fatigue, stress, and anxiety Figure 3.5. Furthermore, both shop floor and managerial employees state that safety concerns and physical workload have gone down and that the number of occupational diseases such as noise-induced hearing loss has significantly declined. Despite the many benefits of digital manufacturing technologies, the respondents also identify some disadvantages. As we already noted, all respondents agreed that mental workload (Mental Workload (MWL))[11] and performance monitoring have significantly increased (further discussion see Section 5.1.4, whereas job security has decreased. Despite these negatives, shop floor workers do not indicate that their job fulfilment has lessened.

Interestingly, our experts anticipate that one of the potential negative impacts on workers' well-being due to change in the work environment could be the absence of human contact or a lack of social interaction. P12L comments,

> *"Thinking about human interaction to how humans might interact with robots and understanding a lot of the way that an organization functions is based on relationships that are developed over a period of time and trust. And a lot of that comes from social interaction and having conversations and finding points of*

10 See also (Brynjolfsson et al., 2018)

11 Also see (Sharples, 2019)

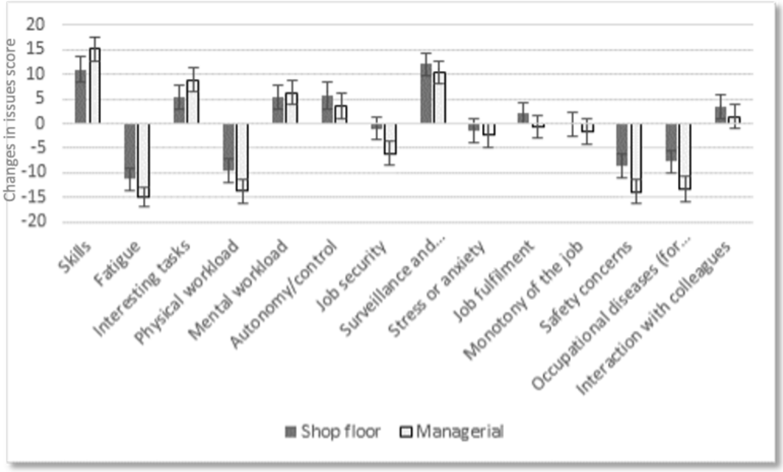

Figure 3.5: Issues around DMTs and robots after technology introduction as a function of the employees' job role.

> *commonality and interest between people. I think when you start to introduce robots, you start to remove from the opportunity to have those social connections and those social interactions. It depends on the level of sophistication of the robot. But I think as an individual and I guess thinking about how that might work in the workplace is how do you address potentially some loss of social interaction and create trusted of relationships that work. So, for example here, we often have to work, we can work really late and part of how you deal with that in the workplace is you have people that you work with in there is camaraderie and so for purely human level, how do you replicate that and can you replicate that if you introduce robots."*
>
> — P12L, Senior Technology and Data Protection Lawyer

Whether this often-expressed fear of loss of camaraderie and social interaction will be a true effect of the introduction of robots in the workplace remains to be seen, as our survey showed that DMT users did not experience a lower level of interaction with their colleagues after the adoption of new (robotic) technology. P5R points out that with all technology introduction a transition period can be difficult, particularly when adapting to different forms of interaction (from co-workers to robots/machines) and the consequences of that have not been explored enough, *"I think the habits that we have about how we interact are very ingrained, but certainly I don't think you could very easily sort of launch a cobot into a workplace and just say 'there you go.' You would expect some kind of issues to arise, but you'll probably find that after a series of time people will be able to kind of develop practices that would be able to accommodate the robot. It'll be an empirical question about whether it's possible to train humans to adapt their interactive style to meet what a robot does or to create a robot that interacts like a human."* P5R also raises a concern where people may interact with robot 'co-workers' in a similar manner to the way they would behave towards each other, but with the difference that the robot does not return any emotions. Such interactions could lead to a negative impact on the workforce. Researchers conducted a study to investigate the behavioural and psychological effects when replacing a human advisor with a machine advisor, and they found that participants "experienced more negative emotions, lower reciprocity, and faulted their advisor more for mistakes when a human was replaced by a machine" (Prahl and Van Swol, 2017, p. 1). Other research found that because humans are social creatures, there could be serious long-term consequences such as diminished organisational commitment and lower productivity when positive emotions that come from social interactions are lost (Oswald et al., 2015). Therefore, it is important that the identified disadvantages and concerns are addressed for the utmost benefits of the introduction of DMTs to be capitalized.

3.3.11.4 *A Route Forward: The Experts' View towards Responsible Adoption*

In considerations to responsible Cobot adoption, understanding the roles Cobot in the workplace and the implications of the adoption will be crucial. The considerations range from ethics around human-robot interaction (HRI) to the future of work. From the first discussion on ethics surrounding HRI, an important question to ask is what is the role of robot in our society and work environment, is it a colleague or a tool? Our interviewed expert, Robot Ethics Senior Researcher P5R raises this debate,

> *"To what extent do you want people to have an emotional attachment when robot rather than human being because you can give effects into a robot but a robot can't genuinely give it back. What does that mean for who we are as human beings as well as sort of the well-being of that person when they commit a lot to a robot in it, but you don't get anything in response to it. And then of course, you know, what kind of roles do we want robots to be taking in society"*
>
> — P5R, Robot Ethics Senior Researcher

HRI and HCI literature frequently grapple with understanding human relationship with artefacts and the impacts of such integration of technology into our daily lives (Coeckelbergh, 2011; Shibata and Wada, 2011; Porcheron et al., 2018; Krueger et al., 2021; Boada et al., 2021; Złotowski et al., 2015; Zacharaki et al., 2020; Coeckelbergh, 2011). Although, this is not a new concern, it is not often brought up in the context of manufacturing where robots are used. However, as Cobots will be taking a new role that is different from traditional industrial robots, this concern needs to be explored further. Even though Cobots are viewed as assistive tools in the Study, we cannot undermine impact of Cobot adoption on people.

On the future of work, the impacts on the workforce need to start with addressing the questions of *"what kind of role robotics will take in the workplace and their role in replacing individuals and how it will work"*, states data protection and cybersecurity lawyer P12L. The lawyer also points out that it is crucial to reflect on how to distribute the responsibility between human and machines and that this needs to be made clear to the employees. Based on experience, technology implementation consultant P10C supports this view, arguing that even though job displacement is almost unavoidable when it comes to the implementation of technology in the workplace, there is still a very important conversation to be had on how to mitigate the negative impacts on the workforce and evaluate the benefits and costs of technology implementation, *"in our view, whatever stage of maturity you're at, the human roles will sort of start to diminish. There are some questions there for government and others; how quickly they want this to happen and where exactly the benefit should be sought and are people protected from it?"* For example, P10C suggests that an environmental impact assessment that is mandatory for the steel and coal industries to protect towns and workers should also be required for DMTs and robotics adoption. The Robot Ethics Senior Researcher P5R shares a very similar concern on how technology can be used to benefit the whole of society: *"everyone is worried about robots taking people's jobs but that's the wrong way of framing it. It's about robots supplementing the job we have already, or if they are taking away jobs, it's done in a way that those who've lost their jobs have a chance to do something different, so it's not a loss for them, it's something that's also a benefit for them."*

When the benefits outweigh costs, it could be rationalised that technology is adopted to help rather than replace people. The ethical questions about job loss may likely be discussed in the light of the purpose of the technology. As P11L points out "Some probably suggest that Cobots would free humans to do more creative stuff or less tedious stuff. There are very few ethical questions about things that assist you." The lawyer continues, "there are ethical questions about the loss of jobs. Although those are kind of balanced to an extent by some developing compelling arguments about how many additional jobs you get from doing this". The justification is that some of the tasks that are replaced by robots are either not ergonomically best for humans, are undesirable, or require a high level of precision where errors can easily occur if done by human workers (Pham et al., 2018). Similarly, the industrial revolution also created a radical change in the industry, although Bejarano et al. (2019) argue that this change gave *"new opportunities and better living standards to the working class since [the] population could focus on areas with superior impact"* [p. 558]. It is important to clarify that adoption of technology in response to employment issue depends on the tasks DMTs contribute to. Quality director P2M expects that there will always be a role for human workers "People will be needed for programming the software and to teach the robots what to do. We will need people to implement new activity and new parts".

Ultimately, job loss due to technology integration will depend on the organisations. The company's organisational culture and its shareholders and/or stakeholders influence how technology will be used and the consequences on the sustainability of the workforce. Technology Ethics Consultant P6C emphasises that organisations can choose to augment the workplace with robotics, or they can choose to supplant all human activity with robotics, *"then it really becomes 'what are they intending to do?'"* Many conversations being had about the potential advantages that Cobot could bring, however, we must ask ourselves whether this is really what is occurring and what are the real advantages and for whom? Is the purpose of Cobots to take the place of human workers, or is the idea to train the robots and have humans retain their roles? Furthermore, are the companies investing in reskilling their personnel, and what is happening with the data that the cobots collect? All of these questions are vital to consider when assessing the impact of cobot adoption as the Technology Public Policy Consultant P4C points out,

> *"One of the thing that's valuable is that even though robots don't replace people, per se, but if you if you add a bunch of robots to a factory there is the chance that, yeah, no, so they do replace people but not wholesale as we sort of worry about, but essentially, as you start to push skilled robots into place that collaborate with humans, the other humans who used to work with them may find themselves out of a job. And in which case the question is, is the company reskilling that employee?"*
>
> — P4C, Technology Public Policy Consultant

Interestingly, despite some of the concerns, P15M notes that their current organisation has a plan for re-skilling workers who are permanent employees,

> *"Within our business, we use directly employed staff and we use agency [staff]. Our trained people that have been with the agency that work for us, but for over a year, they then can become members of staff. In the event that you put robots in, all it does is move our guys from the repetitive and the mundane, to something that is more interesting. It is not added cost, but it is added value, and then the agency [staff] are the ones that move out. for this particular business, I don't think there's an issue per se. I think it might be different if you were a fully recruited business, you probably do it in terms of natural selection, natural turnover, you know, natural waste."*
>
> — P15M, Robotics and Automation Expert

This example serves as an important reminder of the ultimate goal that technology should be used as a complement rather than a substitute for the workforce. The need for a better culture in this regard is paramount, and fortunately, it appears as though we have begun to take steps in the right direction to address this issue.[12]

Lastly, responsible technology adoption should take into account its impact on the environment from several angles. This includes the environmental consequences of the materials used to manufacture the technology as well as the environmental impacts of its usage. Digital manufacturing technology will likely increase a large amount of energy which will result in a larger environmental footprint as the Technology Adoption consultant P9C explains,

> *"There's also an ethical element in the sense of, if I'm using lots of rare materials, stuff that can't be easily recycled. If I'm con-*

12 See also https://interact-hub.org/ for UKRI funded research network focusing on understanding the human issues resulting from the diffusion of digital technology technologies in manufacturing sector.

> *suming lots of electricity and power for doing something that's not really valuable there's an ethical consideration in that too."*
>
> — P9C, Technology Adoption Consultant

Additionally, technology that is designed to be disposed of after its life cycle of use can have an even greater environmental impact. It is therefore essential to consider the entire lifecycle of a technology when considering its environmental impact as the Law and Technology Professor P7L also voices this concern,

> *"We are only beginning to understand some of the environmental impact of the robotic revolution. And it doesn't look good, to put it mildly. The verse example that makes the headlines are things like blockchain and the massive energy consumption that they have neural network. With massive in the energy use,* ***robots require energy that comes from specific sources, because they can't just eat grass. We [as humans] are very efficient in a certain sense of turning biomaterial into energy so that gives a human worker pretty good carbon footprint.*** *Whenever you replace human workers, whenever you think a Cobot environment is a good idea, have you actually calculated the impact that has on your carbon footprint? I think we don't really even have the right methodology is for that, as yet. So I think there's an urgent need to understand in a much more robust and quantifiable way, what are these external costs that automatizing of work process carry with them? What is the environmental impact? The more machines that needs recycling, that needs energy, that potentially use up rare mineral, rare metals, and all that? I think that is often overlooked aspect, but interesting."*
>
> — P7L, Law and Technology Professor

The environment impact assessment for Cobots is yet to be realized, making this point highly crucial. When considering the ethical and social implications of Cobot adoption, the long-term effects must be taken into consideration. Whilst the immediate environmental effects of Cobot adoption may appear to be benign, the long-term effects could lead to much larger challenges. It is therefore essential that a thorough assessment is undertaken to understand the full range of impacts that the adoption of Cobots may have on the environment. The Technology Implementation consultant P10C emphasizes on this point,

> *"We are suffering a little bit from that because the materialism and we're talking about saving the planet and yet, we're using our funds and 6% of our energy is consumed nationally by data centers and data warehouses. So we're not articulating the tradeoffs properly. And that's what we should do and* ***that's why I welcome what you're doing. If anything else we need more."***
>
> — P10C, Technology Implementation Consultant

The sentiment coming from the experts echo the motivation of this thesis: to understand the responsible and sustainable adoption of Cobots in our present and future reality. Understanding both the advantages and drawbacks of Cobot adoption is essential. Although Cobots are not yet ready to be accepted as truly collaborative robots, the potential advantages are acknowledged, and they are still being favorably received by manufacturers with the anticipation that Cobots will eventually attain the ideal degree of 'mental and physical dexterity'. It is promising that Cobot will likely to be integrated as a workforce as technology advances, thus, it is important that our attitudes and practices evolve with it. The adoption of this technology should be viewed as a positive development that increases productivity and efficiency for companies and workers alike. Therefore, taking a step towards responsible Cobot adoption is key where the adoption is respectful and considerate of the workforce and wider stakeholders' including the environmental impact.

3.4 LIMITATIONS

Semi-structured interviews were chosen with open-ended questions in order to cover a wide range of responses and to identify challenges from a variety of different perspectives. We anticipated that if the interview questions were too specific and focused solely on challenges, we might overlook other implications which may not be immediately apparent and concerning to some experts. As certain implications may be seen as a challenge by some, they may not be viewed as such by others, and vice versa. Additionally, the level of concern regarding different implications may vary depending on the expertise and background of the individual. Considering a variety of viewpoints from experts with different backgrounds and specializations can help provide a more comprehensive understanding of Cobot adoption challenges. To answer the main research questions, it was necessary to look for emerging challenges from practitioners' perspectives, which necessitated recruiting a wide range of experts in order to achieve this goal. By having a wide range of views, we can capture a nuance that may otherwise be missed. Literature has demonstrated that peoples' backgrounds can influence their perspectives on a given issue, which we also observed in the Study. However, recruiting qualified participants was quite a challenge, especially finding experts in the relevant fields to collaborative robotics. We also wanted to present the perspective of different experts but due to difficulty in recruitment, this study is not meant to be taken as the general consensus of stakeholder's perspective but rather to act as a starting point of exploring overall challenges in consideration to different stakeholders. Whilst recognizing that the ratio of expertise is not even, it was not within the scope of this PhD thesis to compare and contrast the understanding of different experts and stakeholders.

Furthermore, the Study has certain disadvantages, such as bias in sampling and interviewer and interviewee bias, therefore certain topics might have been explored more during the discussion. We do not claim that the presented findings are conclusive, and they should not be used for generalizations. We recognise that the interviewees from the expert interview study are not necessarily representative of all stakeholders involved in the decision-making process. It should also be noted that many of the interviewees have worked with connected autonomous vehicles. However, it is to be recognized that this technology, as a form of human-robot collaboration, already has various use cases in real-world commercial applications. Importantly, there is an availability of regulatory frameworks and legal analysis for autonomous vehicle technology, which makes the experts' experience valuable and relevant to the UK digital manufacturing sector where human-robot collaboration is still developing. Lastly, for future research, it would be interesting to do a comparative study and engage more with experts who are based in different parts of the world as experts in this study are mostly from Europe whilst a few are from North America.

3.5 CHAPTER SUMMARY

At the beginning of this Chapter, the question is posed: *is it technology or is it really the law?* In other words, are the law and regulatory challenges the biggest hurdle for digital manufacturing technologies (DMTs) and Cobot adoption? The answer is *not really*. Whilst it is true that such challenges can be a burden, they are not the only challenge. In exploring the relationship between law and technology adoption challenges, the Study revealed overall challenges in adoption and acceptance of DMTs and Cobots from different perspectives and disciplines to provide a more complete picture of Cobot adoption. The findings bring forward how law and regulatory challenges are just one of a variety of issues that can impede the successful adoption of Cobots. Throughout this Chapter, several other key adoption challenges have been explored from the most widely known being the cost versus benefit analysis to the less highlighted area of how technology is often oversold in the hopes of enabling it to work effectively with humans whereas in reality, this is not always feasible.

It is recognized that the adoption of DMTs and Cobot changes the nature of work for shop floor workers. It is evident that employees find the introduction of technology to be beneficial from a safer working environment to a decrease in stress level. Equally, there are certain drawbacks such as an increase in mental workload, an augmentation of performance monitoring, and reduced social interaction with colleagues. Particularly, privacy is viewed as a significant trade-off given the intensification of sensors and computing power relying on data from workers' interactions with the machines (including their physical location and movement patterns in the workspace), which possibly introduces a higher degree of workplace surveillance. Such concerns need to be addressed, as they can lead to a detrimental impact on the sustainability of the workforce.

Furthermore, the Study demonstrates that the law is important to support technology adoption while clarity in law is equally important for designers, but the current law is still lacking clarity. The findings certainly call attention to how law and technology must come together to drive adoption although, at the moment, they aren't coming together. The findings also shows that the users don't have sufficient trust to adopt the technology, because they aren't certain about safety (particularly the workers), liability (the businesses, the insurers and the manufacturers) and the data (nobody is sure what data is being captured and who can see it). But without a push for adoption the policymakers are likely to change the law which means that the designers are not going to innovate. For example, the field of autonomous vehicles has seen significant efforts from the motor industry to embrace their adoption. Consequently, the UK government has taken legislative action and tasked the Law Commission with conducting an extensive project to address the necessary changes in the law. The aim is to establish enough trust to allow these vehicles to operate on public roads. However, at present, a similar project focusing on Cobots or smart robots is yet to be initiated.

Moreover, Cobot developers need to overcome the design challenges from the perspective of inclusion where humans in the loop should be the core concept whilst ensuring safety and the ability to override the system. Thus, Cobot design challenge includes finding a balance between the two; a system in which the robot follows the designers' agenda while also enabling the operator to take control when needed. Nonetheless, the insights from the interviewed experts shine the light on the complexity in aligning expectations and standards for ethical Cobot adoption. We observed that the contextual nuances pertaining to safety measures and ethical implications. Thus, the complexity of aligning expectations and standards with regards to ethical cobot adoption has generated a fascinating and diverse range of opinions. All of these opinions contribute to our understanding of the issues and the need for greater transparency and dialogue between stakeholders.

This Chapter answers the thesis RSQ2 *'what are the key legal, ethical and social challenges in the implementation of collaborative industrial embodied autonomous systems in industrial workplace?'* The findings from the Study suggest the key factors that drive technology adoption and acceptance of Cobots as well as the challenges. Therefore, as we continue to navigate this uncharted territory, the knowledge gleaned from the Study proves invaluable in ensuring the safe and responsible adoption of Cobots. For the foreseeable future, Cobots should be viewed as tools that augment human work rather than replacing humans entirely. This Chapter highlights the need to ensure the responsible implementation of Cobots in industrial workplaces and to help drive the adoption and initiating legislative intervention. It is only by understanding the implications and challenges of future Cobot adoptions that we can ensure robots are used responsibly and how the law can play a role in the route forward in Chapter 4.

4

UNPACKING LEGAL FRAMEWORKS IN THE CONTEXT OF COBOT ADOPTION CHALLENGES

Is 'Cobot Law' necessary?

Contents

4.1 CHAPTER OVERVIEW

Following the findings from Chapter 3, this chapter investigates the role of law in addressing Cobot adoption challenges. The Study reveals several challenges: adoption of new technology, trust, risk, safety, due diligence, regulatory, ethics and social challenges, data & privacy, design, and insurance. Notwithstanding that Section 3.3.3 concentrates around the fundamental discussions of law and technology, the findings signify that the law is not the only factors in the slow adoption of Cobots, albeit there is a debate on a perceived gap in Cobot regulation. As the primary objective is to understand the relationship between law and technology adoption specifically in the context of Cobots, this requires an analysis of the applicability of existing regulatory frameworks to address the challenges identified. This chapter is organised in two parts: (1) Analysing the regulatory gap by situating Cobot in the context of AI and robot law (2) Addressing the specific regulatory gap by examining adoption challenges from the perspective of data protection law.

In the first part, we analysed the continuous development in AI and robot regulations including the lessons learned from robot law and the conventional discussions on safety and liability challenges posed by autonomous systems. One of the potential answers to liability and safety challenges surrounding robots and automation points towards the use of data collected by robots. This is a controversial approach considering contrary to data protection principles.

In the second part, we examine the role of data protection laws and the applicability of such doctrine in ensuring safety and accountability of Cobot adoption by manufacturers.[1] To highlight, data and privacy concerns are at the core of the adoption framework as demonstrated in Figure 3.3. Thus, tackling data and privacy challenges, we foresee that it will create a cascading impact on addressing other adoption challenges found in Chapter 3. On that account, the legal analysis primarily focuses on the General Data Protection Regulations (GDPR). Additionally, in light of Health and Safety at Work etc. Act 1974, we argue that data protection must be viewed as part of an employer's obligation to ensure the safety of employees at work through adequate safeguards and relevant assessments on the use of Cobots where safety stemmed from both interaction with Cobots and the data collected by Cobots. Thus, unpacking the GDPR within the context of Cobot adoption becomes imperative. This chapter will en-

1 It should be noted again that manufacturers in this context are companies in manufacturing looking to adopt DMTs, including Cobots, in their production line or manufacturing plant. Whereas we used the term robot provider/manufacturer to specify the companies which provide Cobots to manufacturers.

deavor to provide insight how the data protection law can facilitate responsible adoption of Cobots in manufacturing.

In addressing the criticism towards the perceived gap between technology and legislation can largely be attributed to a lack of familiarity with the subject matter, specifically Cobots. Without adequate knowledge, it can be challenging to determine the appropriate approach towards regulating emerging technologies and discern the role of legal mechanisms within this realm. In this chapter, the Study findings from Chapter 3 offer valuable insights that enable a comprehensive examination of existing legal frameworks, yielding fruitful outcomes.

4.2 PART I: REGULATORY GAP, YOU SAY?

Robotics has been integrated into manufacturing lines since the time in the 1950s. Recently, smart industrial robotics have been designed for the purpose of human-robot collaboration (HRC), such as an autonomous robot trolley transporting goods within a factory. Another example is a collaborative robot designed to work next to human operators, handing over equipment and parts in an assembly line. This emerging robotic technology is what we consider Cobots in this thesis as highlighted in Section 2.3.1. This new generation of industrial robots would allow for a more flexible and lean process and maximisation of efficiency at work. With human-robot collaboration, the advantages are the combination of high levels of accuracy, strength, precision, speed, endurance, and repeatability from the robot and the flexibility, sensitivity, creativity, and cognitive skills from the human. However, Cobots are yet to be widely adopted and in most cases the robots are still kept in a cage, at least in the UK. We have identified the adoption challenges in Chapter 3 but the question is, how has the regulatory system responded to this emerging technology?

In Section 2.4, the pertinent legal frameworks concerning the regulation of Cobot adoption were elucidated. It was preliminary determined that the aforementioned frameworks are inadequate for Cobot adoption as they neither adequately address human-robot collaboration nor provide sufficient assurance regarding safety considerations. However, in more recent developments, the European Union (EU) has recognized the necessity to "update" the Machinery Directive 2006/42/EC, which consequently was repealed by the introduction of Machinery Regulations (EU) 2023/1230 of the European Parliament and of the Council (Regulation (EU), 2023/1230). This revised regulation aims to harmonize health and safety requirements for machinery, including the realm of human-robot interaction (HRI). Notably, this regulation has great potential in ensuring the safety of Cobots, and thus is favorable to Cobot adoption, as to allay concerns related to the perceived lack of regulation given the defined responsibilities and obligations imposed upon robot provider/manufacturer regarding the safeguarding of robotic systems in HRC scenarios.

Article 10 specifies that *"when placing machinery or a related product on the market or putting it into service, manufacturers shall ensure that it has been designed and constructed in accordance with the essential health and safety requirements set out in Annex III."* Annex III outlines the safety requirements including risks related to moving parts where HRC and HRI are addressed as in accordance to Annex III (1.3.7),

> *"The moving parts of the machinery or related product shall be designed and constructed in such a way as to prevent risks of contact which could lead to accidents or shall, where risks persist, be* ***fitted with guards or protective devices****...the prevention of risks of contact leading to hazardous situations and the psychological stress that may be caused by the interaction with the machinery shall be adapted to:(a) human-machine coexistence in a shared space without direct collaboration; (b) human-machine interaction."*

Notwithstanding the apparent possibility and adaptability in modifying guards or protective devices whilst adhering to regulatory requirement to facilitate HRC and HRI, under Annex III (1.3.8.2),

> *"Guards or protective devices designed to protect persons against the hazards generated by moving parts involved in the process shall be: (a) either fixed guards as referred to in section 1.4.2.1; or (b) interlocking movable guards as referred to in section 1.4.2.2; or (c) protective devices as referred to in section 1.4.3; or (d) a combination of the above."*

In this case, the installation of guards might counteract the intended function of Cobots, as the guards would prevent contact with the machine, thus hindering human operators from working collaboratively with the Cobots. Therefore, robot providers/manufacturers may resort to invoking the provision pertaining to protection devices, whereby workers can utilize wearable or similar instruments to assist in safety interaction with the machine. Consequently, ensuring safety have to be viewed from different perspectives, as mentioned above, "risks of contact leading to hazardous situations and the psychological stress." In light of these considerations, the utilization of wearable sensors presents a viable option in in supporting both effective and safe human-robot interaction. For instance, Al-Yacoub et al. (2020, p. 651) developed "a hardware setup and support software for a set of wearable sensors and a data acquisition framework" where the data collected from the sensors can help robot identify "human physical and psychological states such as muscle fatigue, frustration and anxiety" so it can interact accordingly.

However, despite the potential solution in the utilization of wearable sensors to fulfill safety requirements, it remains plausible that the expected level of human-robot collaboration is still unachievable. In accordance to Annex III(1.4.3),

> *"Protective devices shall be designed and incorporated into the control system in such a way that: (a) moving parts cannot start up while they are within the operator's reach; (b) persons cannot reach moving parts while the parts are moving, and (c) the absence or failure of one of their components prevents starting*

or stops the moving parts. Protective devices shall be adjustable only by means of an intentional action."

It is evident that the concept of a protective device still prioritizes the objective of halting robot operations in close proximity to humans. Whilst Annex III (1.3.7) acknowledges the need to adapt measures in the context of HRI and HRC, it could potentially deter robot providers/manufacturers from producing the technologies as the prevailing requirements still pivot towards promoting physical separation between humans and robots as a means to uphold safety. Therefore, it could be challenging for robot providers/manufacturers to demonstrate compliance of machinery with the essential health and safety requirements in case of HRI and HRC.

The new machinery regulation has been adopted in an effort to address safety and liability concerns surrounding the rise of autonomous machinery including the uptake of human-robot collaboration, albeit it is still unclear as to how it defines the safety requirements to facilitate such collaborations. As the regulation is mainly directed at all machinery and not specifically to human-robot collaboration, it raises the question as to whether or not Cobots should be subject to a separate, more stringent regulation?

4.2.1 *From Cyber Law to Cobot Law: Lessons Learned from Easterbrook, Lessig, and Calo*

Examining the role of law in regulating emerging technologies has come a long way and will continue to evolve in particular the debate whether (emerging)[2] technology should be regulated under specific, separated, legal frameworks, such as 'robot law'.

This started with the introduction of cyberspace. Easterbrook (1996), raised an intriguing question: should cyberlaw be regarded as a dis-

2 in retrospective to the time of the existing regulation e.g., the World Wide Web is no longer an emerging technology, but it certainly was in the late 1990s where the law was being challenged by the sudden eruption of the internet.

tinct field of legal study or as a branch of traditional legal doctrines? This question arises from the fact that the legal challenges posed by cyberspace encompass various aspects of law. Easterbrook's comparison to the "law of the horse" illustrates the argument that understanding cyberspace requires an examination of its impact on a wide range of legal frameworks, and attempting to establish it as an independent domain of law further complicates matters due to incomplete comprehension of both technology and law. To quote judge and professor Frank Easterbrook, remarking on the comparison of cyber law and the Law of the Horse, noted that such area of law *"is doomed to be shallow and to miss unifying principles"* (Easterbrook, 1996, p. 207).

Establishing cyberlaw as an independent domain was rather complicated owing to the lack of in depth understanding of both technology and the law; however, this controversial debate marks the early days of technology law with an interdisciplinary research approach to unpack aspects of technology and the need to examine its impact on a wide range of legal doctrines in order to bridge the gap between law and technology. Over the years, researchers have worked to address the legal challenges of emerging technologies, drawing together insights from different disciplines. Such an approach is especially important in addressing criticisms that a regulatory gap arises from law being far behind technological advances (Brownsword et al., 2017).

In light of Easterbrook's perspective, Lessig (1999) offered a different approach to understanding cyberspace's unique characteristics and the challenges of integrating it into traditional regulatory frameworks. Lessig proposed four regulators of cyberspace: market, law, architecture, and social norms. Architecture refers to the regulation of cyberspace through code, which dictates its operations. Whilst this intrigues the new discussion on the potential of code as law (see (Brownsword, 2022; W. Li et al., 2015; Yeung, 2019), this is not within the scope of the PhD thesis. However, it is crucial to recognize the significance of technology itself in the regulatory framework. The market aspect considers how businesses respond and adapt to the internet, as its uptake depends on their actions. Social norms, meanwhile, shape user behavior and influence the success or decline of the internet. Finally, the law encompasses the set of rules that regulate activities in cyberspace, determining what is permissible, establishing liability, and assigning responsibility.

Building on Lessig's work on establishing methods and norms of cyberlaw, Calo (2015) posits that the law will face challenges in regulating transformative technologies such as robots due to the 3 distinct characteristics that make an artefact a robot: embodiment, emergence, and social valence. Embodiment allows robots to sense, navigate, act in the real world. Emergence signifies a robot's autonomous behaviors lending to their ability to 'learn.' Social valence is how a robot feels different to us from other technology, where it is more similar to a living agent than a mere tool. Due to these characteristics, Calo (ibid., p. 552) concluded that robots would likely to influence systematic changes to the law as remarked,

> *I too propose a moderate conception of legal exceptionalism for purposes of assessing robotics. A technology is not exceptional merely because it creates one or more small changes in the law, or because it reveals, at the margins, that an existing interpretation of a particular doctrine is incomplete. By the same token, a technology need not occasion a literal breakdown in the rule of law or prove the source of entirely novel doctrines to qualify. Rather, a technology is exceptional when its introduction into the mainstream requires a systematic change to the law or legal institutions in order to reproduce, or if necessary displace, an existing balance of values.*

Cobots are transformative technology, a type of robot that performs as a robot co-worker rather than performing tasks independently and only co-existing in the same space as humans. Calo's statement has highlighted the need to reevaluate the current legal doctrine, but we have been warned that this may require the formulation of a new legal doctrine. Will *Cobot Law* be necessary?

The lessons learned from cyber law and robot law provide a valuable insight to Cobot regulation. We find that the regulation of emerging technologies requires a greater understanding of not only the technology itself, but also its consequential impact. To this end, it has become increasingly evident that interdisciplinary research is necessary in order to examine the role of law in this field. By examining the technology from different perspectives, a more comprehensive understanding can be gained. In addition, the ubiquitous presence of the internet instills a sense of optimism that the legal system is adaptable and constantly evolving to accommodate the advancements in technology. Given this historical precedent, it is reasonable to anticipate a promising future for Cobots. Nonetheless, taking from cyber law to robot law, regulating Cobots will require an integration of the need to situate technology in the wider legal doctrines and explore the potential in creating new rules to govern the emerging technology. So before hastily establishing a new regulatory framework for Cobots, we must first assess the existing legal doctrines in light of heightened knowledge and comprehension of the technology. As we progress, we will start to draw more from the Study findings to help inform the legal analysis. We will begin by addressing the liability and safety concerns associated with the adoption of Cobots.

4.2.2 *Redress res ipsa loquitur: Robot Speaks for Itself*

As previously discussed in prior sections, the significance of reevaluating the legal framework in the context of emerging technology is apparent. This section examines the applicability of the current legal system in responding to the novel challenges posed by embodied autonomous and the proposed liability approaches discussed in literature for addressing the complexities of dealing with robots.

Undeniably, accidents can arise regardless of the actors involved, be it interactions between humans or humans and machines. However, the existing legal system has primarily been designed to address human-only scenarios, leaving those involving machines subject to more nuanced considerations. Notably, when a machine functions as a mere tool with fixed programmed functions, identifying liability for accidents is more transparent where robot providers/manufacturers are held accountable for any defects or malfunctions in their products that cause harm. On the other hand, if a machine possesses certain level of autonomy, with the ability to learn and adapt in a manner resembling human behavior, determining liability becomes more intricate. Traditionally, tort law relies on identifying negligence or fault attributable to legal persons (Miceli, 2017). However, the advent of autonomous machines, that to certain extent are mimic human behaviours, raises questions about how damages caused by such machines should be treated within the legal system?

4.2.2.1 *What the "Law" Says*

In the EU, efforts to establish regulations for robots and artificial intelligence (AI) are underway. However, as of time of writing, there are no definitive guidelines to rely on, apart from the new Machinery Regulations (EU) 2023/1230, which do not fully accommodate the concept of HRC. Nevertheless, ongoing legislative developments hold significant implications for the potential regulations concerning Cobots in determining responsibility in cases where incidents occur, leading to damages or harm caused by robots and/or AI systems.

Starting with Civil Law Rules on Robotics (2017), the adoption of mandatory insurance emerges as a prudent regulatory approach. This viewpoint is highlighted by our interviewed experts, as discussed in Section 3.3.7, where insurance serves as a crucial gatekeeper in facilitating the adoption of cobots. In accordance Section 57,

> *a possible solution to the complexity of allocating responsibility for damage caused by increasingly autonomous robots could be an obligatory insurance scheme, as is already the case, for instance, with cars; notes, nevertheless, that unlike the insurance system for road traffic, where the insurance covers human acts*

> *and failures, an insurance system for robotics should take into account all potential responsibilities in the chain.*(Civil Law Rules on Robotics, 2017, Section 57)

As highlighted in Section 3.3.3.3, is recognized that robot is a complex non-human agent, comprising of component from different providers from hardware to software. In the event of an accident, insurance coverage must encompass all parties responsible inconsideration to the maker and user of robot, including the robot providers/manufacturers, software provider, maintenance personnel, and even the operator. Hence, all parties involved in the entire lifecycle of Cobot, from its design and development to its deployment, must collectively share the responsibilities to ensure comprehensive coverage and accountability.

The approach of distributing responsibilities across all relevant stakeholders may prove to be a prudent way to address damages caused by autonomous robots. By doing so, we can avert the complexities of determining fault between "unknown" causes e.g, software failure, hardware issues, or human actions. Through shared responsibilities, we can effectively address these concerns and foster a more cooperative and accountable environment, ensuring that each party plays a proactive role in mitigating potential risks and liabilities associated with autonomous robots. This also reflects Section 59 which outlines the requirements for the mandate insurance in relation to the damage potentially caused by the robots. It also suggests for possible legal solutions such as,

> *"the manufacturer, the programmer, the owner or the user to benefit from limited liability if they contribute to a compensation fund, as well as if they jointly take out insurance to guarantee compensation where damage is caused by a robot; d) deciding whether to create a general fund for all smart autonomous robots or to create an individual fund for each and every robot category, and whether a contribution should be paid as a one-off fee when placing the robot on the market or whether periodic con-*

> *tributions should be paid during the lifetime of the robot*(Civil Law Rules on Robotics, 2017, Section 59).

Notably, the regulations and liability rules need to take into account the distinctions among different types of robots and their respective levels of autonomy. In accordance to Section 56,

> *"Considers that, in principle, once the parties bearing the ultimate responsibility have been identified, their liability should be proportional to the actual level of instructions given to the robot and of its degree of autonomy, so that the greater a robot's learning capability or autonomy, and the longer a robot's training, the greater the responsibility of its trainer should be; notes, in particular, that skills resulting from 'training' given to a robot should be not confused with skills depending strictly on its self-learning abilities when seeking to identify the person to whom the robot's harmful behaviour is actually attributable; notes that at least at the present stage the responsibility must lie with a human and not a robot"* (**.**)ResolutionCivilLaw2017

This provision proves particularly advantageous for Cobots, as highlighted in Section 2.3.2, considering the varying levels of engagement and interactions they can have. For Cobot adopters, this provision serves as a valuable tool in preparing for risk assessments and ensures that they do not bear undue responsibility in respective to the type of Cobot. By aiding in the determination of risk and potential liability, this provision provides pivotal support for cobot adoption.

Moreover, when taking into account the various levels of robots, the EU Artificial Intelligence Act (EU AI Act) proposal introduces different tiers of responsibilities for AI systems. However, contrary to what was stated above in Section 56 of the Civil Law Rules on Robotics, where the operator's liability and responsibility are determined by the actual level of instructions given to the robot by the operator and of a robot's degree of autonomy, this proposal centers around AI's potential to cause harm. It is acknowledged that under Recital 63, *While safety risks of AI systems ensuring safety functions in machinery* *are addressed by the requirements of this Regulation, certain specific requirements in the [Machinery Regulation] will ensure the safe integration of the AI system into the overall machinery, so as not to compromise the safety of the machinery as a whole.*" As AI serves as the cognitive foundation of Cobots, the software plays a pivotal role in ensuring their efficient and safe collaboration with humans. Therefore, this Regulation is applicable to Cobot.

Furthermore, in accordance to the EU Legislation in Progress Briefing, a common strict liability regime for high-risk autonomous AI systems is favorable where "operators of a high-risk AI system would be held liable when such systems cause harm or damage to the life, health, or physical integrity of a natural person, to the property of a natural or legal person, or cause significant immaterial harm resulting in a verifiable economic loss" (Madiega, 2023). As AI would likely to play a critical role in safety aspect of HRC, in light of Article 6, Cobots will likely to fall under the classification rules for high-risk AI systems. Moreover, Article 3(8) defines that term 'operator' as "the provider, the user, the authorised representative, the importer and the distributor." As it refers to all stakeholders, there is still the absence of a clear direction in determining liability which may bring us back to a debate concerning who should be held responsible for damages caused by autonomous robots. Therefore, the proposed shared insurance responsibility, as suggested in the resolution on Civil Law Rules on Robotics, could be a viable solution to support Cobot adoption. With this approach, all relevant stakeholders can collectively share the responsibilities, resulting in a more equitable and efficient resolution of liability concerns. Nonetheless, scholars appear to be reluctant to endorse a blanket policy for AI technology. Bertolini and Episcopo (2021, p. 658) highlighted that "the EU should pursue continuity in its sectorial approach to regulation. AI will be used in diverse fields – from capital markets to medicine – where liability is currently regulated separately, and so they should continue to be so even when AI-based solutions are implemented."

4.2.2.2 *Proposed Liability Approaches*

In the effort to regulate autonomous machines, numerous liability approaches have been proposed, ranging from treating robots as animals to assigning "electronic personhood." Additionally, the imposition of a strict liability approach and the redressing of the legal doctrine of res ipsa loquitur in light of robots have also been put forward.

In the work by Kelley et al. (2010), it may be feasible to consider robots in the legal sense as to domesticated animals, in particular the regulation for 'dangerous dogs,' in grappling with the complexities of autonomous robots that have a degree of independent decision-making and control over their actions, distinct from remotely controlled or pre-programmed robot. From a perspective of a robot involving in an accident and found to be free from defects, the courts should assign liability to both the victim and the robot's owner based on the same principles are domesticated animals. The authors concluded that

> "many of the restrictions employed to control dangerous dogs can be easily adapted to deal with robots. For example, all of the following can be applied to robots with almost no change at all: microchip tracking, liability insurance requirements, owner-displayed warning signs, adult control while in public, special identification while in public ("robot collars"), and expanded notification requirements." (ibid., p. 1867)

The authors also proposed for strict liability for robot providers/manufacturer in instances of robot defects, while holding owners accountable for negligence, such as damages caused by the robot's unpredictable behaviors resulting from inadequate maintenance and wear and tear. The authors recognised that in Europe, harms caused by domestic animals can resulted in criminal and civil penalties, categorizing them into "dangerous dogs" and "all other dogs." The idea of classifying robots based on their potential to cause harm is also shared by the EU approach to the AI Act as discussed previously.

Therefore, in the same ways as domesticated animals, robots cannot compensate for potential damages they may cause, this perspective allows for a more coherent and practical approach in addressing the liability challenges associated with these advanced technologies. This proposal may be more applicable in the context of domestic robots but the underlying principles can be applied in the context of industrial workplace. As Cobot's adopter, the manufacturers, will still need to ensure safety and routine maintenance of Cobots in order to ensure safety because they can still be held liable for harms caused to the employees.

On a different discussion, as we have outlined this discussion in Section 2.4.3, could a Cobot ever be considered as a legal person (i.e., "ePerson") where it can be considered as a wrongdoer and qualified as liability subjects based on tort law? Granting a robot legal personhood is certainly a highly contentious debate (see (Pagallo, 2018)). In fact, machines should not be regulated in a similar manner to people as Eidenmuller (2019, p. 133) argued *"our laws are an expression of the human condition. They reflect what we believe lies at the heart of humanity, at the heart of what it means to be human. It simply and literally would be the dehumanizing of the world if we were to treat machines like humans, even though machines may be smart—possibly even much smarter than humans."* Though it was viewed that a concept of an ePerson could help simulate innovation given that it provides *"protection of manufacturers and users from excessive liability"* (G. Wagner, 2019, p. 612). G. Wagner (ibid.) argued that the reach the same outcome on determining liability of robot providers/manufacturers and users, it is simply unnecessary to create a new legal entity as ePersons - bearers of rights and duties and holders of assets in a similar way to a corporation. To hold a robot as an ePerson liability for damages will require a robot having minimum asset requirements which robot providers/-manufacturers and users would have to contribute to this asset pool.

However, this can still occur if these parties were obligated to obtain mandate insurance for the robots, as also proposed in Civil Law Rules. This indicates that the necessity of creating a new legal entity such as an "ePerson" to address liability issue in the context of insurance may not be required.

Although it has been concluded, at least for now, that robots should not be granted a legal status, the question of how to address the accidents caused by Cobots, as a new cause of harm, still remains. Guerra et al. (2022a, p. 332) raised a concern that "as the level of robot autonomy grows, under conventional torts or products liability law it will become increasingly difficult to attribute responsibility for robot accidents to a specific party." The scholars proposed for a liability model addressing that "a fault-based liability regime where operators and victims bear accident losses attributable to their negligent behavior, and manufacturers are held liable for non-negligent robot accidents called 'manufacturer residual liability'" (Guerra et al., 2022b).

With a fault-based liability regime, the process of determining the extent to which each party should contribute to compensate for their negligent behaviors may be challenging. This complexity arises from the possibility of attributing blame solely to the autonomy of the robot and its unpredictable actions, which could lead to the argument that the incident was not a result of negligence (Casey, 2019). presented a different approach in applying tort law in the case involving robots. The author highlighted that *"tort law doesn't require that plaintiffs pinpoint direct evidence of accident fault in a faulty line of software. Instead, the legal rule of res ipsa loquitur allows plaintiffs to show fault through inference even in accidents involving confoundingly complex machines."* (ibid., p. 252). In tort, *"to invoke the maxim res ipsa loquitur [...] it is a necessary factor in the application of the maxim that the pursuer does not know, and cannot reasonably be expected to know, the cause of the event giving rise to the accident"*(Birch v George McPhie & Son Ltd, 2020). In dealing with autonomous robots, high level of safety should be expected, thus, if a robot cause any form of damages that would not have been foreseeable, presenting a good ground for a case of negligence.

According to (Casey, 2019, p. 233),

> *The legal system has successfully dealt with complex, software-driven accidents many times before using age-old approaches. And, thanks to the sophisticated data recording technologies embedded in modern robots, these longstanding liability regimes offer an especially elegant solution to the purportedly "confounding" challenges raised by automated accidents. To navigate autonomously, robots must constantly sense their surrounding environments. As a natural byproduct, they create richly detailed, multisensory records of the events that transpire around them. Thanks to these robust data-logging capabilities, authorities can reconstruct automated accidents with a degree of granularity simply unimaginable in conventional contexts. Rather than getting bogged down in algorithmic esoterica, they can look for the inference of negligence55 in the machine's own meticulous account.* ***The robot, in other words, speaks for itself****."*

This is also supported by G. Wagner (2019) where the data stored in the "black boxes" installed in autonomous systems will enable victims to readily and precisely identify the party responsible for any incidents. Therefore, in tort problems involving the determination of liability for damages due to negligence, data can often infer negligence. In the context of robots, the doctrine of res ipsa loquitur, which means "the thing speaks for itself," may be complicated. When an accident occurs involving a robot, access to relevant data can allow for drawing inference of the cause. This facilitates the process of attributing responsibility and liability for the damages caused.

Nonetheless, Pagallo et al. (2017) examined the case of accountability of autonomous systems from the perspectives of criminal law and civil law. The author concluded that,

> *some cases brought on by AI technologies that, sooner or later, will induce national and international legislators to intervene*

> *in the fields of criminal and civil law. All in all, legislators are confronted with three different kinds of challenge. They concern (i) the specific features of AI technology; (ii) the competition between regulatory systems; and, (iii) how to address such challenges at a meta-regulatory level."*(Pagallo et al., 2017, p.21)

In the future, it is plausible that Cobots may require a distinct set of regulations when the existing legislation can no longer cope with the challenges arising due to the nature of highly advanced autonomous systems. Alternatively, it might be necessary to amend the current regulations to address the data that should be retained by Cobots. However, until an intervention takes place, the adoption of data logs as evidence in handling liability cases related to data seems to be the most plausible and feasible approach. Therefore, this puts data as a pivotal and central point in Cobot regulation which we will delve into a comprehensive analysis of this matter within the context of the General Data Protection Regulation (GDPR) in Part II. In the next section, we will discuss the implications of data from the context of health and safety and the need for inclusion in data training requirement for Cobot safety.

4.2.3 *Data Meets Health and Safety Regulations*

At the end of Part I introduction, we posed the question of whether Cobots should be subject to a separate, more stringent regulation in addressing safety and liability challenges. We proposed that given how data plays a crucial role in determining negligence, it should also be regulated in the context of safety regulations, wherein the responsibility rests with the robot adopter. As Cobots are integrated into work environments, manufacturers are obliged to ensure the adoption is aligned with health and safety regulations. Our empirical study, under Section 3.3.8.3 and Section 3.3.9.3 highlighted the importance of data utilization in training robots to ensure their safe interactions with diverse users. For example, designing robots that are trained with data from a specific demographic, such as white 6′1" men, could be considered a breach of the Health and Safety at Work Act if it leads to a situation where the robots are deemed "not reasonably safe" for interactions with individuals from diverse backgrounds.

Furthermore, in Section 3.3.5.2, our experts emphasize on the significance of data in algorithmic bias. Cobots interact with humans and making 'judgements' about the humans through the collection and processing of personal data, such as data derived from user behaviors, facial expressions, voice, and biometric data (e.g., heart rate sensoring) to adapt to their performance, as observed in the mentioned article (Ali et al., 2019). If the robots are training on poor data sets, this could have implications on how the robots will behave in the real environments with different users. For instance, if a robot recognizes and responds to a male voice better than a female voice during the operation, this form of discrimination raises safety concerns. Therefore, failure to address such bias can result in hazardous workplace scenarios. In tackling this challenge, it should be highlighted that the responsibility for Cobot safety lies with both the manufacturer adopting Cobots (acting as the employer) and the Cobot provider/designer.

In the UK, Health and Safety at Work etc. Act 1974 the employer has the duty to "ensure, so far as is *reasonably practicable*, the health, safety and welfare at work of all his employees," where the duty includes:

> *in particular(a) the provision and maintenance of plant and systems of work that are, so far as is reasonably practicable, safe and without risks to health; (b) arrangements for ensuring, so far as is reasonably practicable, safety and absence of risks to health in connection with the use, handling, storage and transport of articles and substances [...]* (Health and Safety at Work etc. Act, 1974, Section 2)

In light of Section 40, reasonably practicable actions should be interpreted as taking all possible actions until it is *"not reasonably prac-*

ticable to do more than was in fact done to satisfy the duty or requirement, or that there was no better practicable means than was in fact used to satisfy the duty or requirement." This places the employer in a position of responsibility to prioritize the protection of employees at all costs, thus playing a crucial role in safety of Cobot adoption since they are in the position in determining how and which Cobots are adopted in the workplace. Therefore, companies will be held accountable if any accidents occur due to inadequate assessment in Cobot design or failure to ensure that they procure, to the best of their knowledge, suitably designed Cobots.

Furthermore, Health and Safety at Work etc. Act (1974) Section 6 requires that,

> *"it shall be the duty of any person who designs, manufactures, imports or supplies any article for use at work or any article of fairground equipment(a) to ensure, so far as is reasonably practicable, that the article is so designed and constructed that it will be safe and without risks to health at all times when it is being set, used, cleaned or maintained by a person at work; (b) to carry out or arrange for the carrying out of such testing and examination as may be necessary for the performance of the duty imposed on him by the preceding paragraph"*(ibid., Section 6)

Under Section 53 'article for use at work' means *""article for use at work" means(a) any plant designed for use or operation (whether exclusively or not) by persons at work, and (b) any article designed for use as a component in any such plant""* whereas "plant" includes any machinery, equipment or appliance.

As part of Cobot safety assessment, it is the robot provider/manufacturer's responsibility to thoroughly address all aspects that contribute to the technology's safety, including the incorporation of appropriate training data for Cobots. Biased and discriminatory resulting algorithmic decision-making can can lead to unsafe interactions, thereby making it a case of health and safety regulations. In such instances, it becomes the designer/manufacturer's responsibility to ensure workplace safety. Therefore, data used in Cobot design and training should have been addressed within the health and safety risk assessment. Being that, the robot designer/manufacturer ensures that their training data include all possible types of users in the intended context while the employer is accountable for selecting a Cobot provider that prioritize inclusive user-centric approach in their design.

In addition to training data, the data collected by Cobots is also crucial as the technology requires data to perform its tasks and interact in a safe way with its environment (See Bdiwi, 2014; Avanzini et al., 2014; Fryman and Matthias, 2012; Wachter and B. Mittelstadt, 2019). Even though the constant data processing can be argued from the perspective of safety monitoring or even considered as evidence in the event of accidents, this could raise concerns about over-monitoring or surveillance practices. This can to increasingly problematic privacy issues given the constant interaction of robots with humans (Leenes et al., 2017a; Gardner, 2016). Hence, given the pivotal role of data in Cobots, the adoption of Cobots in the UK and the EU will necessitate a data protection impact assessment in accordance with the General Data Protection Regulation (GDPR) which will be explored in the next section.[3]

4.3 PART II: COBOT ADOPTION AND DATA PROTECTION REGULATION

As previously mentioned in Section 2.4.5 and Section 3.3.4.2, Cobots are equipped with diverse sensors and algorithm-driven systems that enable them to interact with and process information from the real environment. Furthermore, Section 4.2.2.2 suggested that data collec-

3 We acknowledge the ongoing development in amending the UK GDPR; however, as of the time of writing, the UK GDPR remains in effect. Since the subsequent sections address data protection principles that remain unaffected by the amendment from the EU GDPR to the UK GDPR, we will refrain from delving into the distinctions between the two regulations and continue with the original GDPR as of REGULATION (EU) 2016/ 679

ted by Cobots should be stored in the case of accidents involving robots in addressing the liability gap of embodied autonomous systems. Therefore, when manufacturers implement Cobots, they are in a position of data controller of the personal data processing by the robots. In the EU and the UK, the GDPR governs the accountability of both algorithmic systems (Article 22) and those who are of data controllers (Article 24).[4]. Under Article 25, the regulation places all responsibility on the data controllers to perform their obligations that the adopted technology is data protection by design and by default (DPbD). The caveat is that the GDPR only applies when personal data processing takes place. In principle, Cobots need to collect data from its surrounding where the physical space also include interaction with humans. Therefore, it can be argued that the data collected and processed by Cobots blurs the line between the environmental or ambient data and personal data, and thus is subject to the GDPR. This then presents the first legal implication for manufacturers to understand and address what are the personal data processing activities by Cobots.

Furthermore, once the activities are identified, data controllers are required to conduct a data protection impact assessment (Data Protection Impact Assessment (DPIA)) when the processing activities may result in high risks to the individual rights and freedom. Cobots process data to effectively respond to the environment, particularly in their interactions with human workers. During such interactions, Cobots also engage in profiling[5] activities, analysing and evaluating hu-

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4 Also see further discussion in(Kaminski and Malgieri, 2020)

5 Under GDPR Article 4(4), "profiling' means any form of automated processing of personal data consisting of the use of personal data to evaluate certain personal aspects relating to a natural person, in particular to analyse or predict aspects concerning that natural person's performance at work, economic situation, health, personal preferences, interests, reliability , behaviour, location or movements" whereas recital 71 cites that automated processing means "such processing includes 'profiling' that consists of any form of automated processing of personal data evaluating the personal aspects relating to a natural person, in particular to analyse or predict aspects concerning the data subject's performance at work, economic situation, health, per-

man workers' movements and performance. While this profiling aims to enhance collaboration, such as slowing down if a human is tired or alerting the manager, it can also pose risks to human workers if this data is used against them, thereby requiring more safeguards (Gellert, 2016).

Thus, the DPIA is an essential tool in monitoring compliance and ensuring that manufacturers are demonstrating their duties in complying with data protection principles and taking ownership over algorithmic accountability, fairness, and transparency of Cobots. Although Article 35(7) sets out a list of requirements on what a DPIA needs to contain to demonstrate compliance, as the regulation is technology neutral, the requirements are quite vague and can lead to difficulty in conducting adequate assessment. We find the challenge is twofold: establishing what are individual rights beyond the explicit data protection rights under the GDPR and determining when a high risk may occur in a Cobot adoption context.

Whilst the applications of DPIA under the GDPR have been widely implemented, the emerging advanced technologies like Cobots, which involve collaborative interactions between machines and human workers, along with the diverse types of data collected, presents challenges in demonstrating GDPR compliance. Therefore, we view these challenges of GDPR compliance as the key requirements that need to be unpacked in order to help inform policy to create a clear guideline for data controllers in navigating their accountability for Cobot adoption. The following sections elaborate on the requirements for complying with data protection regulations from three angles: understanding personal data, identifying individual rights, and establishing a high risk to the rights and freedom of natural persons.

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sonal preferences or interests, reliability or behaviour, location or movements, where it produces legal effects concerning him or her or similarly significantly affects him or her."

4.3.1 *Personal Data or Environmental Data?*

As previously described, Cobots are equipped with sensor technology which provides greatly data collection capabilities. In Section 3.3.4.1 Robotics and Automation Expert made the argument that the sensor data are not quite personal data. However, in the context of the interpretation of the GDPR, sensor data can be personal data. The adoption of Cobots present new ways for data to be collected given its interaction with human workers and other software and systems within the space of manufacturing given the socio-technical systems aspect so not only what Cobots are collecting but also what data are they sharing with the wider systems and vice versa. Cobots collect and correlate multiple sensor inputs persistently even though the data collected at the surface may not be personal data, it has the potential to be used to infer or identify individuals. Although environment and personal data are very distinct by definitions but given the vast amount of data collect by Cobots, it can become difficult to make such distinction as arguably any information is likely to be related to a person given the proliferation of data and progresses in data analytic. We conclude that in most cases data collected by Cobots are personal data providing the definition of personal data under the GDPR and the interpretation discussed in literature and case law.

In accordance to Article 4 of the GDPR, personal data is "means any information relating to an identified or identifiable natural person ('data subject'); an identifiable natural person is one who can be identified, directly or indirectly, in particular by reference to an identifier such as a name, an identification number, location data, an online identifier or to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person" (Regulation (EU), 2016/679). By this definition, the data collected by Cobots particularly concern the physical, physiological, and location data which are directly related to individuals. Moreover, the interpretation of personal data is broad, and therefore, even environmental data can be considered personal data given the followings. A three-step model can be used to form the basis to assess what is 'personal data.' The assessment looks at the content, purpose, and result of the data processing; if any of these aspect is either directly or indirectly related to an identifiable person, it is considered as personal data (Purtova, 2018). This model demonstrates that any information, even though it may not be personal data by definition presented above, but if the result of data processing could lead to an identifiable person it is considered personal data.

Furthermore, a ruling in Peter Nowak v. Data Protection Commissioner outlines that any form of opinions, comments and evaluation on the data subject in which can have an "effect" on or relates to them and their private life are their personal data; this landmark case sets a broad definition of personal data (C-434/16, 2017). Consequently, Ivanova argues for the case where automated processing operations may not be within the scope of the data protection regulations as no individual is identified or singled out, but as it may be possible for sensitive information to be inferred and create group profiles, such activities should be considered as personal data processing and fall under the purview of data protection regulation (Ivanova, 2020).

Moreover, the Article 29 Working Party acknowledged that, "more often than not, it is not the information collected in itself that is sensitive, but rather, the inferences that are drawn from it and the way in which those inferences are drawn, that could give cause for concern." (ARTICLE 29 DATA PROTECTION WORKING PARTY, 2013, p. 47). Providing this background and a broad scope of personal data, even seemingly innocuous data collected by Cobot can potentially be used to identify individuals, especially if the system correlates multiple sensor inputs from other DMTs. Persistent records can be used for inferential analytics to reveal information and predictions about behaviors and preferences that would otherwise remain private (B. D. Mittelstadt and Floridi, 2016). There are several techniques that can be embedded in Cobot to monitor the employees in particular when

Cobot is linked to the wider system of the factory. For example, a inference techniques and algorithms can be used to reconstruct user location traces from the time-series occupancy measurements (Wang and Tague, 2014). Knowing the employee's movement pattern and their location can be used to inferred sensitive data (e.g., religion, race, health), for example, if an individual frequently visit a prayer room or uses disabled access routes.

Although the result of inferred data is a prediction instead of a factual observation, such inferred sensitive data that can potentially lead to an identification of the individual should still be treated within the scope of personal data. As we see here, environmental data collected by Cobots can become personal data through the use of inferential analytic that reveal information and predictions about behaviors and preferences of the human workers. Therefore, the understanding what is considered as personal data should be the first requirement for manufacturers to determine their processing activities and their duties in complying with the GDPR.

4.3.2 *Identifying Individual Rights*

In the previous sections, we have demonstrated the implications of data and profiling activities conducted by Cobots in assisting their interaction with human workers. Providing extensive evaluation of human workers given the level of personal data processing activities, manufacturers will be expected to conduct a DPIA upon adopting Cobots or when changing how Cobots are used. In this section, we address the requirement to identify individual rights in a context specific manner.

We started by drawing the scope of individual rights under the GDPR and their implications on accountability of Cobots in the context of the DPIA. In accordance to Article 35 of the GDPR, the DPIA is required *"where a type of processing in particular using new technologies, and taking into account the nature, scope, context and purposes of the pro-*

cessing, is likely to result in a high risk to the rights and freedoms of natural persons, the controller shall, prior to the processing, carry out an assessment of the impact of the envisaged processing operations on the protection of personal data."(Regulation (EU), 2016/679) However, the rights covered under the GDPR are not always clear. This challenge can cause data controllers to fail in identifying all relevant individual rights and thus resulting in failing to implement appropriate technical and organizational measures to protect individual rights. Therefore, we examined the rights under the GDPR and highlighted the discussion points manufacturers, as data controllers, must consider from the context-specific rights that are not explicitly stated in the GDPR in order to implement adequate safeguards to protect employees. As Kaminski and Malgieri (2020, p. 69) argues that "even if individuals (data subjects) fail to invoke their rights, companies (data controllers) have significant obligations—both procedural and substantive—under the GDPR" (ibid., p. 69).

Individual rights under the GDPR are, but not limited to, right to be informed, right to rectification, right to restrict processing, right to object, and right to data portability. We did not intend to provide an overview on these rights in detail providing that there are a number of interpretive guidelines available (see EDPS, n.d.; ICO, n.d.). Thus, the discussion is focused what other individual rights may entail in a specific sector engaged in the adoption of embodied autonomous systems. Under Recital 4 of the GDPR, individual rights are addressed as fundamental rights as enshrined in the EU Charter of Fundamental Rights. Scholars also supported that whenever the use of impactful technology is intended the fundamental rights may herewith become mandatory to data protection impact assessments as to give teeth to the protection of these rights (Wright, 2011; Mantelero, 2014; Janssen, 2020). Furthermore, Recital 75 of the GDPR specifies the consequences of risks to the rights and freedom of natural persons due to the application of new technology which include physical, material or non-material damage, discrimination, financial loss, damage to reputation, or other significant economic or social disadvantages. In this case, it can be contended that reversing the consequences can aid in identifying the individual rights that should be addressed concerning the processing activities (Ivanova, 2020). For example, if the processing could result in discrimination, this would signify that individual rights to equality and non-discrimination principle should have been considered.

In addition to what is explicitly stated in the GDPR and the EU Charter of Fundamental Rights, Janssen argues that individual rights under various European Directives should also be referred to, particularly rights in related to specific 3 categories: traits (e.g., ethnicity, gender), domains of professions (labor rights, pensions, or access to and the supply of goods and services), and procedural rights (Janssen, 2020). The last point is interesting as Cobots are equipped with systems enabling automated decision-making and monitoring raises a question on how employees know how decisions are made and how that may impact them. For example, behaviours can be influenced by users' privacy awareness in the online domain and their choice of websites and data sharing (Mandler et al., 2016). This logic may also be applied in Cobot adoption context. Data subjects as employees have rights including freedom to expression and right to peaceful assembly. If people feel like they are constantly being watched and evaluated, this could lead to fears to act freely and it could change how to behave or how they communicate with each other and out of fear of being spied upon. In this case, they may perceive their freedom rights are being violated. This is particularly crucial under employment rights.

With the possibility of constant monitoring due to the use of DMTs and Cobots, the concept of quantifiable workplace may applied here even without the wearable devices(P. Moore and Piwek, 2017). Though workplace surveillance may be necessary to a certain degree for health and safety, this practice is recognised to have an adverse impact on employees and their perceived working conditions as the Study also highlighted (see Section 3.3.4.1. There should be a mutual trust between employees and employers, however, workplace monitoring can intrude into employees' private lives, undermining respect and confidence for the correspondence with their employer (Office, 2011 [Online].). Although the extent of impact monitoring has on employees may not always be immediately realised, privacy in the workplace is a known issue which can heighten in Cobot context.

Moreover, concerning the data collected by Cobots, manufacturers as employers and data controllers must also take into account the individual rights of employees, particularly with regards to copyrights, as discussed in Section 3.3.4.2. While it might be justifiable to assert such data usage based on employment contracts or legitimate interests under the General Data Protection Regulation (GDPR), any utilization of this data for profit-oriented purposes which beyond the employment obligation may give rise to copyright law concerns. In such cases, employees could potentially assert their moral rights as authors of the data. Therefore, manufacturers need to consider applicable copyright laws.

Furthermore, in light of Recital 71, manufacturers would be expected to implement technical and organisational measures to "prevents, inter alia, discriminatory effects on natural persons on the basis of racial or ethnic origin, political opinion, religion or beliefs, trade union membership, genetic or health status or sexual orientation." Therefore, it is within employee's individual rights to be treated equally and fairly. If a Cobot fails to recognize an individual's command owing to the nuances of their accent, consequently leading to work deliverable delay, this can be viewed that an employee was discriminated by a Cobot due to their racial or ethnic origin. This emphasizes the crucial need to incorporate inclusion in design as an essential component of technical safeguards as part of obligations to protect individual's rights under the GDPR.

Therefore, manufacturers as data controllers must consider the impact of the processing activities on the employees to ensure that individual rights are respected. The key takeaway of this requirement is the need to identify individual rights in a context specific manner in order for data controllers to perform their relevant legal obligations whilst protecting the employees. Undoubtedly, data processing by Cobots plays a pivotal role in facilitating collaborative task performance between Cobots and human workers. Nevertheless, it is imperative that such processing activities maintain transparency at all stages. To fulfill their duty as an employer and a data controller, they need to ensure that employees also understand how the data processing by Cobots are used and what data are collected.

4.3.3 *What is Considered as High-Risk?*

Failing to evaluate the risks could lead to the infringement on the rights and freedoms of individuals; such violations could have a serious implications on the accountability of Cobots and the organisation's ability to implement a proactive approach in demonstrating compliance with the regulation to protect the personal data of individuals. However, the factors contributing to a high risk under the GDPR is different from tradition risk management. This challenge causes difficulty and uncertainty for data controllers to conduct a DPIA. In this section, we presented the discussion on risks from two different perspectives: socio-technical and legal. The discussion is aimed to demonstrate the different viewpoints to risks which cause ambiguity in the DPIA, hence highlighting the requirement to establish a threshold of a high risk processing in the context of Cobots in consideration of both perspectives.

4.3.3.1 *From a socio-technical perspective*

The concept of risks from a socio-technical perspective come in several measurable forms. In Section 3.3.6.1, experts discussed various aspects of risks and risk assessments that may arise with Cobot adoption. These risks are closely linked to safety concerns, particularly the potential damages that Cobots might incur, along with the associated costs. Additionally, the degree to which a mitigation strategy can be implemented to avert such damages is a critical factor in evaluating risks. Furthermore, these risks are examined from a technical standpoint, employing the Failure Mode and Effects Analysis (FMEA) method— a systematic technique used to assess systems, designs, processes, or services for potential avenues through which failures, problems, errors, risks, and concerns might manifest (Stamatis, 2003).

Furthermore, Cobots as part of digital manufacturing where the machines are considered to be industrial internet of things are prone to risks in the context of safety and security (Urquhart and McAuley, 2018). Minoli et al. (2017, p. 278) provided examples that "less than 10% of all IoT products on the market are designed with adequate IoT security (IoTSec)." In addition, it can be particularly difficult to identify and allocate responsibility to the multiple stakeholders involved in the creation, development, operation, maintenance, and use of Cobots. The engagement between different actors and providers can lead to a complex agreement to data sharing and processing. This can result in a potential lack of control over managing and monitoring access points access points which can make Cobots prone to security risks and vulnerabilities.

Through a socio-technical perspective of risk analysis, it can be viewed that once these risks are identified and addressed, the threats are resolved. However, these risks are contributing to factors concerning data protection. When examining these risks in the light of data protection regulations, they shift from the technological pitfalls to potential impacts on the employees' rights and freedom in which is intrinsic in the legal disputes where we will examine next.

4.3.3.2 *From legal perspective*

In this discussion, we will first explore the overall concept of a high risk to a right and its controversial debate and follow by its implications in the context of Cobots. This discussion is the pinnacle of the

DPIA to ensure the accountability of the algorithmic systems. The misalignment in what is a high risk could lead to an overlook of certain processing activities by Cobots that might be violating the data protection principles, leading to failing to protect individual rights.

High risks under the GDPR concern the likelihood of individual rights and freedom being violated. We recognise that Article 29 Working Party has provided an in depth analysis on the nature of 'high risk' which they categorised into nine examples including processing of combining datasets, special categories of personal data (e.g. health data, racial or ethnic origin, etc.) and data concerning vulnerable data subject, large-scale monitoring of publicly accessible areas, and innovative use of data for new technological/organizational solutions (Urquhart et al., 2018; ARTICLE 29 DATA PROTECTION WP, n.d.). This guideline is quite broad in spite of the explanation on what processing activities would constitute as high risks. It is recognised that the interpretation of high risk to a right, as aforementioned, needs to also be defined in a context specific. However, there is a limited evidence in supporting the discussion of to what extent constitutes as a high risk under the DPIA in a sector specific context (Demetzou, 2019).

Particularly, the interpretation and evaluation of risks are determined by the controllers in relation to their origin, nature, details, and severity, which can be subjective. This is due to the fact that the introduction of DPIA is viewed as novel risk-based approach to data protection regime, hence the novelty comes a lack of resources. To unpack this, the comparison is drawn between the DPIA and its predecessor Privacy Impact Assessment (PIA), environment impact assessment, and other technology impact assessments in the hope of navigating the DPIA approach and understanding the risks (Gonçalves, 2020). However, it is worth noting that the DPIA is not a replacement of the privacy impact assessment (PIA). The DPIA is viewed as a sub-set of the PIA given that the DPIA concentrates around data protection compliance issues whereas a PIA considers all dimensions of privacy

(Sion et al., 2019). In an attempt to conceptualize a risk a right under the GDPR, Gellert argues that the risk subject to Article 35 is to viewed as "compliance risk" meaning that "the lower the compliance the higher the consequences upon the data subjects' rights" (Gellert, 2018, p. 1).

Furthermore, Sion et al proposed systems to help quantify risk in order to determine the 'high risk to individual rights.' The system incorporates the concepts and requirements imposed by the GDPR into the architecture of risk management modeling to estimate the impact of a certain threat to a data subject's rights. The authors argued that "quantifying that risk allows controllers to tailor the scope of their compliance duty, implement data protection by design, and guarantee the security of their activities" (Sion et al., 2019, p. 3). Against this example, other scholars presented the arguments on the pros and cons of quantitative risk-based approach in the use of existing risk management methodology as a supporting tool when conducting a DPIA to assess a risk to a right and whether that is sufficient enough. Van Dijk et al. (2016) highlighted the need to apply legal knowledge to DPIA as opposed to only treat it as another risk assessment using existing methodologies. As we explored this concept of risk to right from the context of Cobots, it is difficult to determine high risk to freedom when the subject itself is perhaps obscure when the discussion on freedom is contentious (Beck, 2013).

Consequently, the right to privacy is equally complicated as it has many facets. To simply put, the perception towards privacy is unique to each individual. Equally, the privacy tolerances also vary. Henriksen-Bulmer et al. (2020) used the examples of the tagging clothing to enable identification of someone's whereabouts and the use of smart meter to illustrate how different individuals constitute an attack on privacy. They suggested that with the former it is perceived as an invasion of privacy, however, people do not have a problem allowing their utility suppliers to monitor the usage although it would be possible to use the data to pinpoint the location of their home, the time they're home and/or using the data to infer their preferences. With this study, it may imply that a risk to a right can be interpreted as a translation of perceptions towards the data controllers in which contributes to people's privacy valuations. If people see that the data sharing is for the purpose that is beneficial to them they will not likely see data sharing as privacy invasion such as how a smart meter ensures the flow of supply and the convenience in monitoring and reporting energy consumption. By this assumption, manufacturers will need to consider employee's concerns and understand what they perceive as benefits and what is considered as an invasion of privacy. For example, Ali et al. (2019) demonstrates how wearable sensors can help with better HRI, however, employees may find such implementation intrusive.

Nonetheless, the right to privacy is at risk in the connected space with constant data collecting and processing, as this problem has been a known challenge the start of computing Solove, 2005. In the context of Cobots, the right to freedom closely tie to privacy such as to be able to perform tasks without being watched, judged, or evaluated. Therefore, it is a double edge sword whereas data processed by Cobots can help with better HRC and address liability challenges, but it might interfere with other right such as right to privacy.

Although a DPIA takes on a risk-based approach to assess the impacts of the processing activities on individual rights, treating such risks in a similar manner to other risk assessment methodologies is proven to be complicated as individual rights and freedom cannot easily be quantified and most of the times, they are conditional. Where the empirical studies highlighted the perceptions towards risks in Cobot adoption, a future work with a focus on establishing a standard protocol and clear risk assessment for manufacturers to determine high risks data processing by Cobots in relation to individual rights and freedom is required.

Overall, although compliance with regulatory requirements should be a given, the requirements of the General Data Protection Regulation (GDPR) should be seen as an opportunity to ensure that privacy concerns are addressed and employees' trust in Cobots and and digital manufacturing technologies is improved. We posit that DPIA should be seen as an opportunity to deeply interrogate and manage the privacy risks. Methods of employee involvement in the DPIA process should be considered, and completed DPIA need to be shared with employees. Second, in order to ensure data privacy for employees and in accordance with Article 25 of the GDPR, when introducing DMTs, employers must put in place appropriate organisational and technological measures that are designed to implement data protection principles. This requirement to ensure data protection by design and default must both influence choices about the technology to be adopted in the workplace and animate the design of processes surrounding the implementation of these technologies. For example, principles of 'data minimisation' should provide a basis for policies governing sharing and retention of data regarding employees; the principle of 'purpose limitation' should influence the ways that collected data are utilised. Third, once a DMT is adopted, employers must provide information to employees regarding the purposes for which data are processed, along with details regarding the employees' rights as data subjects. For instance, if certain data will be used for performance improvement or process optimisation, employees must be informed of such activity. The communication needs to be delivered in a simple and short format and it needs to be easy to understand. This information should be seen as the minimum, and employers should continuously communicate with employees regarding adopted technologies, the data that are collected, and the uses that they are put to. Clear communication and transparency can help ease and mitigate privacy concerns on perceived heavy workplace surveillance. In addition to the standard data protection training in relation to handling personal data, training specifically on the interaction with the robots and sensors should be provided.

4.4 CHAPTER SUMMARY

At the beginning of this Chapter, the question is posed *Is 'Cobot Law' necessary?* The answer is *not yet*. The law operates on an outcome-based approach, wherein reaching the desired outcome requires thorough research and analysis. This, however, should not be mistaken for an "outdated" or ill-equipped nature of the legal framework to regulate current form of Cobots. On the contrary, the law's adaptability lies in its ability to contextualize such technology appropriately. The field of cyber law and robot law has made substantial advancements over time, offering valuable insights and lessons for Cobots. The lessons provided the direction in unpacking legal frameworks as rather than focusing on developing novel legislation entirely, it is more prudent to apply and examine the existing legal frameworks to Cobot adoption in light of interdisciplinary research perspectives.

In this Chapter, in answering RSQ3, we have extensively examined various legal doctrines aimed at tackling the challenges surrounding safety, liability, data, and privacy issues in the context of Cobot adoption found in Chapter 3. While the existing machinery regulations acknowledge machine design for HRI, the safety requirements seem to fall short in fully supporting HRC. On the front of liability perspectives, we have identified several approaches, with the proposal on insurance and data retention emerging as particularly well-suited for Cobot adoption. Consequently, data also plays an important factor in ensuring safety for HRC which should be duly considered under health and safety regulations. Moreover, the subject of data collected by Cobots containing personal information may encounter conflicts with data protection principles. Nevertheless, through a comprehensive analysis, we have demonstrated that appropriate safeguards and measures under data protection laws can be effectively implemented to address these challenges.

Thus, the law plays a pivotal role in enhancing the safety of technology, encompassing several critical aspects. From the Human-Robot

Collaboration (HRC) standpoint, it involves ensuring the adequacy of training data and data processing methods. Moreover, the law addresses concerns related to surveillance, safeguarding the rights of employees in their interactions with robots. Despite initial expectations of a regulatory gap, our findings demonstrate that the law has significant influence over the safety of robots and serves to provide clarity on liability concerns.

Undeniably, as Cobots continue to advance, it is reasonable to anticipate a proportionate increase in challenges. As highlighted by (Liebert and J. C. Schmidt, 2010), the full effects of a technology often become apparent only when it is fully integrated and utilized. Nevertheless, this does not imply that current technology cannot be effectively regulated under existing regulations.

5

THESIS CONCLUSIONS

To what extent can the law address the adoption challenges raised by collaborative industrial embodied autonomous systems (Cobots)?

Contents

5.1 SUMMARY OF FINDINGS AND DISCUSSIONS

Section 1.2.1 outlined the research question that this PhD thesis aimed to explore. To effectively address the overarching research question, we formulated three research sub-questions, which served as crucial building blocks in the pursuit of answering the thesis research question. In this section, we reflect on the thesis findings in answering the research question and the accompanying research sub-questions.

5.1.1 *Working with Speculative Concepts of Cobots*

RQ: To what extent can the law address the adoption challenges raised by collaborative industrial embodied autonomous systems (Cobots)? In answering this thesis research question, we first need to understand what are Cobots in the context of Industry 4.0 (RSQ1).

The Criticism towards a 'Cobot'

From the very beginning, we emphasized the importance of anticipating the future of Cobot technology and working towards understanding the challenges and implications of such adoption. When work on this thesis began, the term 'cobot' was being questioned and heavily criticized. The term was often referred to as a piece of marketing hype or as representing unrealistic technology. We experienced considerable skepticism about conducting research on this technology. However, the criticisms were helpful in pushing us to explore further on this topic since everyone seemed to be intrigued by the topic but very little has been unpacked. It became the mission to first understand the technology and what is a cobot. In doing this, in Section 2.3.1 we reviewed and analyzed the term cited in literature, from academic scholarship to industry publications to legal instruments. We also situated this type of robots within digital manufacturing technologies (DMTs) where it provides an introduction of wider implications of Cobots as part of the digital technology ecosystems and lessons learned from previously implemented technology applicable to Cobots.

Furthermore, the approach of conducting research based on speculative technology rather than focusing on the current state of Cobots was also questioned. However, we found that as technological advancements could take place swiftly, it was essential to consider a forward-thinking approach aiming to understand the future of Cobots as demonstrated in Section 2.3.3. Neglecting to do so could make our research efforts and outcomes obsolete. Thus, it is important to anticipate future scientific developments and employ them in our research agenda.

The Results

In our examination of the term "cobots," we have encountered a broad spectrum of definitions, a diversity that is also evident in the empirical research (see Section 3.3.1), where experts present varying perspectives, ranging from robots working alongside humans to robots collaborating with each other. As a result, there arose a necessity for a comprehensive term that encompasses the essential characteristics and future potential of these robots. Recognising "cobot" as an evolving term, for the purpose of this PhD thesis, we introduced the term "collaborative industrial embodied autonomous systems," or Cobot. Our definition of Cobot is an umbrella term that includes the types of robots that are designed to work in collaboration with humans whereas collaboration comes in different forms as explored in Section 2.3.1. This definition allowed us to work towards exploring the future of Cobots and their adoption challenges in Chapter 3 and Chapter 4, fostering a deeper understanding of their implications on the existing regulations in governing emerging technologies.

5.1.2 *Cobot Adoption Challenges and Implications*

After establishing what is a cobot, the second part to answering the thesis question requires the understanding of what are the legal, ethical, social and organisational challenges and implications of Cobot adoption in digital manufacturing (RSQ2).

Following the literature review in Section 2.4, we conducted empirical research in exploring the challenges further given the limited literature on this topic. On the discussion of adoption challenges, it became evident that a multitude of stakeholders play a significant role in the process. The research findings highlighted that the adoption challenges are not exclusive to a single group of stakeholders.

Instead, the challenges and implications of adoption apply to all involved parties. Throughout the exploration of various themes, the concerns raised resonate equally with designers, developers, manufacturers seeking to implement the technology, and regulators. Each group bears responsibility in supporting Cobot development and adoption in digital manufacturing. It's in the collective interest of all stakeholders to work together to ensure a successful and secure future of cobot adoption.

Law and Technology: Same Difference

Furthermore, the adoption challenges are multi-faceted as demonstrated in Figure 3.3. Contrary to our initial hypothesis, given the concern raised by our industry partners, the ten themes identified in the Study have highlighted that Cobot adoption challenges extend beyond simple assertions that Cobots cannot be adopted and used as intended due to inadequate legal frameworks or regulatory gaps. Instead, the complexities lie in multiple dimensions, particularly the technology itself, which is not yet ready for adoption, at least for the intended purposed (see Section 3.3.9). The analysis led us to conclude that the challenges related to Cobot adoption are as significant for legal considerations as they are for design aspects. These two aspects are intertwined and must be addressed in a balanced manner to ensure the successful integration and responsible use of Cobots. Because the law does not impede innovation; rather, its purpose is to safeguard users' interests (see Section 3.3.3). Much like technology, the law evolves over time and requires periodic updates, but this does not signify that it lags behind technological advancements. Both law and technology share a similar development trajectory—beginning with a solid foundation that serves its purpose for a period, but eventually necessitating revisions or redesigns. However, unlike technology, the law does not become entirely obsolete; it possesses the capacity to adapt and remain relevant for a considerable duration. This adaptability ensures that the law continues to protect users while accommodating evolving societal and technological landscapes.

Communication and Acceptance

Moreover, on exploring different themes, certain aspects echoed familiar challenges associated with embodied autonomous systems, including safety, liability, and data protection. However, within each theme, numerous intriguing observations emerged, emphasizing the crucial necessity to delve deeper into each area to comprehensively address the adoption challenges for future work. Notably, points of interest include the discussion on job displacement and the intricacies of design challenges. For instance, based on the general overview, there might be assumptions of resistance from workers in Cobot adoption, however, our manufacturing experts found that people were quite accepting of robot adoption. This observation reveals that in practice, the situation appears to be different, indicating a positive reception. Nonetheless, the experts expressed a clear and effective change management strategy was in place when introducing new technology to their production lines, particularly emphasizing how they engaged and communicated with their employees. Furthermore, the experts emphasized that the adoption of technology was driven by the need to address labor shortages. We acknowledged that this might not be the case for other organisations however it shows that communication and employee's engagement has a positive impact on acceptance level of Cobot adoption.

New perspectives on Design

From design challenges, as demonstrated in Chapter 2that collaboration comes with many level, it seems that we have achieve the first form of being safely existing in the same space but not at the level of truly collaborative robotics. At present, while it appears that cooperation between robots and humans is on the horizon, the capability necessary to allow for true collaboration is still far off. Developing the technology to enable robots to understand and interact with humans, and appropriately respond to their needs, is a difficult undertaking. With further research and development, cooperation between robots and humans could become a reality, but for now, the capability level to reach this goal remains elusive for the examined use cases. In addition, when it comes to human-robot collaboration in the manufacturing sector, it may be that we have been approaching it incorrectly. Instead of simply copying what humans do and mechanizing their work, the focus should have been on innovating processes in order to utilize Cobot capability. If innovating process equates to segregation of robots and humans, that will not be the key either. Furthermore, with Cobots, it should not be up to humans to teach robots how to complete tasks, but rather, the robots should be programmed from the start to tackle tasks in different ways. Robots can learn from data, such as observation of what humans do, but there is room to explore the use of other types of data. This could be where general AI poses a problem, and it is something that deserves more exploration. Nonetheless, Cobot design needs to prioritise supplementing the way of work as opposed to expecting humans to work around robots. As Pagallo (2013, p. 192) *"if there is no need to humanize our robotic applications, we should not robotize human life either."*

Moreover, the meaning of terms and how they are used in the context of robots, such as "sensing," requires careful consideration. In the case of robots, sensing involves the use of sensors to gather data, whereas for humans, sensing relies on our receptors, which operate differently from robots. It is essential to establish clear distinctions when describing human-robot interactions to avoid misunderstandings and prevent over-trusting in robots (as discussed in Section 3.3.10. We observed that news and media often exaggerate the capabilities of robots and autonomous systems where the choice of terminology influences these perceptions significantly. Addressing this issue may require linguistic adjustments and adopting a philosophical approach, as explored in Section 3.3.9 where the concept of "cobots can't think" is discussed. This also extends to the notion of trust and how it is interpreted and understood in the context of human-robot interactions. By fostering accurate and transparent communication about robotic capabilities and limitations, we can promote a more informed and balanced view of technology, reducing potential misconceptions and misinformed expectations.

Ethical Considerations

In this thesis, we focused on exploring the ethical challenges arising from the impact of Cobot adoption and the choices faced by manufacturers as adopters. The emphasis was on understanding the ethical implications of Cobot adoption, rather than settling the ethical problems related to decision-making for Cobots to determine the morally correct course of action. The Study brought to light significant ethical considerations in preparation for Cobot adoption that go beyond the common notion of "robots are going to replace us all." For organisations, it is essential to assess to what extent employees have a say in their roles when robot adoption occurs and how risk assessments are conducted. Organizations must take into account the constraints and limitations faced by human workers. Inclusion in decision-making processes is of utmost importance in such collaborations, and this should be approached from a perspective that weighs the costs against the benefits. Costs should not be limited to monetary aspects but also consider the impact on the well-being of employees. a significant ethical theme revolves around understanding the workload of human workers when interacting with robots, particularly the mental workload involved. It is crucial to determine the extent to which human workers can effectively cope with their tasks while collaborating with robots. In the context of ethics, it is imperative to establish guidelines that ensure companies prioritize human workers in risk analyses. Technology should be designed and adjusted to complement and enhance the workforce, rather than expecting employees to adapt to the technology. Upskilling is essential when dealing with emerging technology; however, adopting Cobots with the expectation that human workers will simply have to "deal with it" is not an ethical approach.

Concluding Thoughts

The exploration of Cobot adoption challenges proves to be a multifaceted task, with the findings revealing that these challenges are contextual. Ethical implications and safety standards, for instance, are contingent upon the specific uses of Cobots— the who, how, and why of their adoption dictate the challenges involved. Whilst we have identified relevant Cobot adoption challenges in a general sense, it is crucial to recognize that further risk assessments are necessary for specific Cobot adoption purposes.

The Study also presents a compelling argument against the tendency of popular culture to generalize the extreme impact of autonomous systems (e.g., robot uprising or human extinction [1]), which may not accurately represent the reality. Whilst we may not provide a conclusive solution for Cobot adoption challenges, we have successfully addressed common misunderstandings and generalizations about the adoption of Cobots. It is evident that the implications of Cobot adoption are highly contextual, and as such, the debate surrounding this topic requires heightened scrutiny, including discussions about the perceived barrier of law in the design and adoption of Cobots. A more nuanced understanding of these challenges is essential for informed decision-making and responsible integration of Cobots in digital manufacturing.

1 Such as recent headlines like "AI Could Cause Human Extinction, Experts Bluntly Declare" (Orf, 2023) or "Artificial intelligence could lead to the extinction of humanity, experts - including the heads of OpenAI and Google Deepmind - have warned" (Vallance, 2023)

5.1.3 *Regulating Cobots: Not the Law's First Rodeo*

After establishing what is a cobot in Chapter 2, the challenges of the Cobot in Chapter 3, the third part to answering the thesis question is exploring how can the law respond to the challenges (RSQ3) .

Cobots introduce new risks to manufacturing sectors where machines and humans are traditionally kept separated. The adoption of Cobots and the introduction of human-robot collaboration in industrial space raises many challenges as seen in Chapter 3. It might have been expected that emerging technology will challenge or even break the legal system, pushing and blurring the boundaries of the legal doctrines. However, this is not the first time the law has encountered this problem as we have seen it with prior innovation such as the internet (see Section 4.2.1). Furthermore, the introduction of Cobots may not inherently threaten the existing rules of law; rather, it is the uncertainties surrounding this technology and the associated risks that have posed challenges in reviewing its adoption within the context of the law. Therefore, conducting empirical research as a preliminary step proved immensely valuable in informing the subsequent legal analysis.

Nonetheless, we recognise that there is not a well-defined legal framework specifically tailored to Cobots. However, we posit that rather than developing novel legislation, it is more prudent to apply existing legal frameworks to Cobot adoption. Albeit the law is vague, the empirical study has contributed to filling existing gaps in legal understanding, thereby facilitating a better analysis on the application of existing law in the context of cobot adoption. Although the current regulations on machinery recognised the machine design for a form human-machine interaction but the safety requirements did not seem to fully support direct collaboration between human and robot. However, that does not mean the law is not applicable to Cobots in particular given the current stage of cobots still does not allow for proper collaboration. Furthermore, from liability perspectives there are many proposed approaches that can be taken to address damages caused by Cobots and the case of negligence. In particular we found the proposal on insurance and data retention most suitable for Cobot adoption. Consequently, data also plays a crucial role in ensuring safety for HRC which should be addressed under health and safety regulations. Although the retention of data collected by Cobots containing personal data may conflict with data protection principles, the analysis shows that adequate safeguards and measures can be put in place to address the challenges.

In addition, the notion that law is an adoption barrier or innovation killer needs to be revisited. In reality, the law makes technology safer by holding technology designers/manufacturers accountable, resulting in a longer research and development stage to ensure safety and functionality. However, this does not impede innovation; ideas can still prosper, but the development process may take longer to ensure safety. The doctrinal research chapter on Cobots demonstrates this point from the perspective of HRC with training data and data processing to addressing surveillance to addressing rights of employees in association with working with robots. Contrary to expectations, the regulatory gap is not significant, as the law can effectively influence robot safety and clarify liability concerns.

Furthermore, from a policy perspective, law and regulation have shown significant progress when recognized as needed. Since the beginning of the thesis research in 2018, we have witnessed considerable development in policies and regulations for advanced industrial robotics, such as Industry 4.0 support regulations (UK), proposed AI Act (EU), and the replacement of the 2006 Machinery Directive with the Machinery Regulation 2023 (Regulation (EU), 2023/1230). On the other hand, we have not seen much progress for Cobots in manufacturing. Initially, regulations may have been put on the back burner to encourage innovation, but as the sector matures and risks are realized, countries are now prioritizing the safety of autonomous systems. From our observation, we find that the development rate between law and Cobots is not as far apart as previously claimed. Experts' predictions that law is not the barrier, but rather the technical capability and advancement of technology, hold true. The development of Cobots is not yet ready or suitable for true human-robot collaboration. Therefore, regulations can move fast and it seems that with emerging technologies coming through more proactive approach is being considered or at least we are moving that way. The key lies in fostering interest in understanding the impact of technology adoption in order to drive more innovation towards regulating technology.

In answering the thesis research question, to what extent can regulation address the adoption challenges raised by collaborative industrial embodied autonomous systems (Cobots)? We concluded that the existing legal frameworks are adequate in addressing potential safety, liability, and data privacy challenges and implications arising from Cobot adoption as demonstrated in Chapter 4. Although it is evident that technology regulation requires interdisciplinary work, but this does not mean that all hope is lost. In fact, it is quite the opposite. The ubiquity of the Internet is an example of how law can adapt and evolve with technology. Furthermore, as we learned from cyber law, however, achieving responsible Cobot adoption requires more than just legal requirements; consideration of market dynamics, architectural factors, and social elements also plays a role, as Lessig emphasized (Lessig, 2009). A holistic approach that addresses these aspects will be instrumental in ensuring the successful and adoption integration of Cobots. Our recommendations towards such approached are presented in the following sections. Nonetheless, as Cobots are advancing and when technology finally gets to that point cooperation not collaboration as demonstrated in the CIS model in Section 2.3.1, a new way of regulating Cobots may be required.

5.1.4 *On the Perspectives of Market, Architecture and Social*

Overall, the Study (see Chapter 3) showed a positive reception by the workforce of Cobots and other DMTs, which is encouraging for the future of these technologies. DMTs and Cobots are predicted to free workers from boring and repetitive jobs to focus instead on more joyful, interesting, and rewarding tasks. Other benefits that increase the well-being of the workers are reduced levels of stress, fatigue, monotony, anxiety, physical workload, safety concerns, and occupational diseases. However, there are some negatives that need to be addressed to result in a sustainable workforce. Workforce sustainability is related to happiness, health, and well-being, but also to personal initiative and having the opportunity to be strongly involved in the work. Ways to accomplish worker retention, health, and well-being with the introduction of Cobots and DMTs are to promote increased worker engagement, to recognize employees as experts, to encourage management and representatives of employees to co-operate, to build employee skills by offering training and education opportunities, to reduce stress, and to stimulate self-efficacy (a person's belief that they can be successful when carrying out a particular task) (Le Blanc and Oerlemans, 2016). Broadly speaking, a distinction can be made between interventions that are primarily targeted at individual employees and interventions that are primarily targeted at the organisation. Based on the Study in Chapter 3 we suggest several interventions to stimulate a sustainable digital manufacturing workforce, both on an individual level as well as an organisational level.

Interventions at the Individual Level

Several interventions are targeted at individual employees. First, a strategy to enhance workforce inclusion and sustainability is to encourage greater input of the workforce into the acquisition and safety decisions of the technologies, especially from the people who will have hands-on experience with the technologies (e.g., operators and maintenance technicians). If technology is just forced on workers, they might experience feelings of dehumanisation and devaluation of their profession resulting from this technological innovation, engendering the feeling of being removed from the tasks they undertake. The goal is to augment human capacities instead of replacing them by introducing robotic co-workers.

Second, it is key to increase the job security through better training of employees working in manufacturing. We have seen from our study that employees genuinely worry about losing their jobs because robots might replace them. After all, the emphasis of digital manufacturing technologies is usually on reducing time and costs, despite such a workflow often being perceived as a threat to the skills and livelihoods of shop floor workers. As Van der Heijden noted: "Lifetime employment is no longer guaranteed, as the qualifications that are required for jobs are becoming increasingly complex while, simultaneously, the 'half-life' of these qualifications is be-coming increasingly shorter" (Van der Heijden, 2005). The "half-life of skills or qualifications" measures how long skills are relevant in the workforce. Research suggests that skills generally have a "half-life" of about five years, with more technical skills at just two and a half years (Forum, 2016). Therefore, one can assume that every five years skills will become half as valuable. This means that without additional upskilling or reskilling, the people that are being trained now will not be suitable for the jobs we need them to do by 2026. The new robot–human team collaborations give workers the ability to focus on less repetitive tasks that require a higher degree of cognitive abilities and different skill sets, such as creativity, logical reasoning, and problem sensitivity. Organisations must develop their workforce and provide deeper and more intensive re-skilling experiences, providing their employees relevant time for this learning as part of their change management and future workforce planning efforts. However, these efforts need to consider that the future with robotics and artificial intelligence will bring disruptive change, and the provided training content cannot be primarily based on today's requirements or on past successes (Forum, 2016).

Third, it is important that organisations stimulate better communication between managerial levels and shop floor workers. They need to have regular talks with the workforce to explain the benefits of newly introduced technology to reassure those jobs will not be negatively impacted. As other have previously noted, it is important for a sustainable workforce to "encourage employers to maintain a stable employment relation with their workers, characterised by job security, opportunities for worker involvement in shop floor decision-making and provision of training required for workers to learn how to extract the maximum effectiveness from a machine or production system"(Gertler, 2004, p. 39).

Interventions at the Organisational Level

Other possible intervention strategies are targeted at the manufacturing organisations. First, organisations need to address the privacy concerns that employees voice in relation to an increased use of sensors and other data-gathering technologies in manufacturing by reducing surveillance and monitoring of the workforce. Employees' performance and well-being will decrease when employees feel that they are being heavily surveilled. Although workplace surveillance is already well established, modern technologies introduce even more precise ways to monitor every activity performed by the employees, especially through technologies equipped with sensors. Therefore, apart from walking employees through the technology adoption journey, communication on privacy and data protection is required. Although it can be argued on the grounds of safety and functionality that sensors are required for machines to perform the designed functions and to safely operate and interact with workers, at the organisation level it is about setting a boundary on what data are necessary strictly for operational purposes and what data should be erased if they could potentially be used against the employees.

Furthermore, organisations need to understand and manage the change in mental workload experienced by employees due to the adoption of DMTs and robotics. Our survey findings showed that, although mental workload (MWL) increased after the implementation of new digital manufacturing technologies, stress, fatigue, and anxiety decreased. It can then be argued that an increase in mental workload does not necessarily have a negative impact on an individual's well-being (Alsuraykh et al., 2019). For example, higher MWL can have a positive influence over an individual's engagement with the tasks by improving their concentration, as they must be attentive and agile when performing the task whereas low MWL may lead to boredom-causing mistakes if people's minds start to wander. However, in some cases, if MWL is too high, the task may become unmanageable as employees cannot cope with the demand and fail to complete their tasks. This should be assessed on a case-by-case basis, for instance, a shop floor worker may thrive when MWL is high, whereas a manager may start to get anxious as MWL increases. One may suggest that in order to understand an individual's MWL, constant MWL monitoring could be helpful, as this will allow the system to adjust the workflow in real time according to employee's MWL in order to maintain the optimal workload. However, there is a counter argument to constant MWL monitoring; although the purpose might aim for maximizing adaptive technology adjusting to individual's MWL, employees may feel like they are being constantly monitored and surveilled, which could lead to negative effect on employee's morale and performance. We recommend that organisations should be aware that people have an MWL limit and that it is expected that the implementation of DMTs will increase individuals' cognitive processing as the tasks are shifted to more system-monitoring as opposed to traditionally physical work (Argyle et al., 2021). Therefore, before integrating DMTs into manufacturing environments, companies should conduct a task analysis and incorporate MWL measures to understand how the technology impacts employees' performance or their ability to cope with new task demand. This approach will help employers design a process more appropriately or at least have a better idea of what level of productivity or performance should be expected. For example, a company may choose to monitor the workload involved in a task over a one-week period, performing the task when the new technology is first implemented to capture data to adequately evaluate expected task performance. Another solution could be to provide a virtual space for employees to try out the new technology prior to the implementation to analyse the change in cognitive demands required by the new system or process and how it may have potential impact on fatigue and stress. Nonetheless, if employers choose to monitor workload, it needs to be implemented in a way that respects employees' privacy.

Third, employees need to be recognised as experts whereby the overarching aim is to involve the workforce as end-users in the co-creation of a highly technical and user-led workflow. This can be accomplished by assessing how different types of technology can enhance workers' practice and by facilitating a dialogue with stakeholders in the technology industry. There needs to be a dialogue between industry workforce and technology developers by feeding back data on workers' use of and attitudes towards robotics technology to tool developers. End-users' personal narratives will actively inform the technologies' evaluation process to co-create a workflow where technology works with manufacturing workers rather than instead of them. This involvement of the workforce ties in with the earlier noted strategy of giving employees a say in the technology acquisition phase.

Finally, organisations should strive to increase worker representation. Human-centric approaches could emerge that focus on giving the workforce more control over the process, enhancing their practice, and generally representing a more sustainable option than technology-centric approaches. One way to increase the level of involvement of workers in the workplace and give them more control over processes when introducing new technology is through trade unions (Congress, 2004). Interest in trade unions from manufacturing workers has declined by almost half (48%) since 1995 and new research suggests that by 2040 less than 10% of manufacturing employees will be members of a trade union . The impact on employee rights and well-being of this trade union decline across the UK is worrying because these unions are of great importance for protecting workers' jobs, securing adequate work facilities, and ensuring satisfactory work conditions (e.g., working hours, health and safety, equal opportunities). Balaji (2014) points out that workers whose jobs are insecure need advice, support, and help with getting training so that they have the skills to make them more "employable" if their jobs are restructured or dis-appear. Furthermore, a 2016 report shows that there are 50% fewer accidents in unionised workplaces and that trade union members are more likely to stay in their jobs longer (on average 5 years longer). Unions allow workers to come together in a collective voice to communicate to management their dissatisfaction and frustration. We acknowledge that the impact of DMTs on employment is difficult to be quantified without considering sector specific contexts and the diversity of tasks performed within the same field of occupation. Hence, our proposed interventions advise on understanding the impact of the transition into digital manufacturing in order to stimulate a sustainable workforce.

5.1.5 *Robot Legalist*: The Pinnacle of Multidisciplinary Research*

What does it mean to be a *robot legalist**[2]? Researching the topic of law and robotics has been a challenging yet intriguing journey, filled with efforts to comprehend concepts from various disciplines and synthesize the material to build a cohesive narrative. Along the way, we explored innovative ways to communicate with individuals from differ-

2 This term is coined to illustrate the nature of work in drawing on a multidisciplinary approach to explore the topic of law and robots.

ent fields to gain better understanding of Cobot adoption. Through this journey, we introduced a new concept to encapsulate the subject matter, as we discovered that people hold diverse notions of what 'cobots' are - thus, the new term of 'collaborative industrial embodied autonomous systems' or **Cobots**.

Nonetheless, bringing together different disciplines, including business, law, human factors, and HCI was challenging, but it provided a comprehensive understanding of Cobot adoption. Although bringing together different principles was challenging, it illuminates an almost complete picture of Cobot adoption. Our attempt to merge different disciplines began with understanding existing principles and was further enhanced by empirical study, revealing the interconnected nature of these principles. The interdisciplinary nature of our experts, including lawyers familiarizing themselves with emerging technology, highlights the need to bridge gaps and find common ground when dealing with technology adoption. We hope that the approach of to this thesis will inspire more research in the area of technology and law.

5.2 LIMITATIONS AND FUTURE WORK

We had initially planned for more empirical research; however, conducting research during the COVID-19 pandemic proved challenging with certain constraints and limitations on our study. As a result, we had to alter our research plans, shifting from a focus group study to a collaborative survey study. Though, our objective was to explore the adoption challenges from the perspective of decision-makers or those with influence over the decision-making process. However, we recognise that conducting a follow-up interview study with employees would have contributed towards more comprehensive analysis of the challenge, but we were able to address this to some extent through the survey study in collaboration with our industry partner.

Additionally, whist the legal analysis considers frameworks and legal literature from various jurisdictions (primarily UK and EU), the comparative study of different regulations is not within the scope of this PhD thesis, though it could be a valuable aspect for future work. Furthermore, the legal analysis did not encompass the UK's new data protection regulation, "The Data Protection and Digital Information Bill 2022-23," which could be seen as a gap in the analysis. Given the overwhelming numbers of challenges surrounding Cobot adoption, this thesis only scratches the surface of the broader picture of Cobot regulations. We primarily focused on the key challenges of safety, liability, data, and privacy, as they significantly intertwine with other challenges. A more in-depth research effort is necessary to gain a comprehensive understanding of the various dimensions of Cobots and the challenges that may arise depending on the level and context of their use.

In addition, it is highly relevant to explore and reflect upon the practicality of robot and AI ethics guidelines, including how organizations actually implement and adopt these principles. We have started to conduct a study to map robotics and AI ethics guidelines in the context of responsible innovation evaluation where the research protocol follows Jobin et al., 2019; Lubberink et al., 2017; Vakkuri and Abrahamsson, 2018. In essence, the law operates as an outcome-based governance, but it does not contain steps on 'how-to' achieve such outcomes. In the recent years, we started to see the unintended consequences and harms that caused by advanced technology. Many issues have been brought to light; thus, the concept responsible AI and robotics became vital for the industry. Although responsible AI is not a legal concept *per se*, the law prescribes numerous of obligations in which contributes to responsible technology development, albeit being somewhat vague. As a result, various guidelines and principles are published and advocated by different sectors – government, private, non-profit, research centres – to promote and simplify the concept of Responsible AI or AI ethics.

Furthermore, there is a pressing need for more research to identify existing tools and gaps in order to design a toolkit or unified compliance mechanism for responsible technology adoption. This toolkit should be easily understood and implementable by all parties involved, providing comprehensive guidelines to support the policy-making process and navigate the various challenges while mitigating their impact. Scholars already recognize the limitations of Asimov's laws Murphy and Woods, 2009, emphasizing the necessity for further research on responsible AI and robotics guidelines. Such guidelines should be referred to in a similar way to 'Asimov's law,' a widely known set of principles in influencing robot development. Though, the new set of rules will also create a new culture and what that will look like and, as Calo (2015, p. 563) puts it, *"how the law reacts is up to us."*

5.3 CONTRIBUTIONS AND KEY CONCLUSIONS

This thesis explored the question of *to what extent can the law address the adoption challenges raised by collaborative industrial embodied autonomous systems (Cobots)?* In addressing the relationship between law and technology adoption, we have undertaken an interdisciplinary approach, first conducting an empirical study to understand the challenges of cobots and then examining the existing legal frameworks for regulating cobots against the challenges.

On the empirical work, the thesis findings contributed to the literature on technology adoption, in particular, human-robot collaboration and technology law literature. We explored Cobot adoption challenges by taking on an exploratory approach. We found the expert interview approach to be the most suitable method for the purpose of this study, which is to gain in-depth insights from multi-stakeholders' perspectives with most of the experts having more than 15+ years of experience in the field relevant to technology adoption. Applying thematic analysis to our interview transcripts, we capture and present the main concepts revealed by the participants. The Study reveals that adoption challenges are complex and nuanced, involving factors like the distinction between trust and acceptance in the workplace.

Furthermore, Cobot adoption challenges need to be explored from the developmental stage to adoption. We have created a Responsible Cobot Adoption Principles Framework (Figure 3.3) in addressing the different challenge themes: adoption of new technology, trust, risk, safety, due diligence, regulatory, ethics and social challenges, data & privacy, design, and insurance. The framework illustrate how the themes intertwine, reflecting the fundamental factors for responsible Cobot adoption across three layers. The innermost layer comprises technological requirements and guiding principles that foster trust in the second layer where gaining acceptance from stakeholders, including employers and employees interacting with Cobots, is the ultimate objective of Cobot adoption. Each challenge theme should be addressed independently but considered simultaneously during different technology stages, from design to development and adoption of Cobots.

On the doctrinal work, the empirical studies provided valuable insights for analyzing relevant legal frameworks and principles in addressing Cobot adoption. The doctrinal findings indicate that current legal frameworks are sufficient in responding to challenges related to safety, liability, and data protection & privacy. Thus, the law itself does not hinder Cobot adoption; instead, it is the technology's capability that currently falls short of expectations. However, addressing Cobot adoption challenges will require more than legal efforts alone.

To conclude, this thesis addresses the knowledge gap surrounding Cobot adoption by clarifying the definition and understanding of this technology, conducting a comprehensive study on adoption implications and challenges, analysing diverse perspectives on regulating Cobots, thus bridging the gap between theory and practice in this emerging field. It contributes to responsible technology adoption, prioritizing human well-being in manufacturing. The law can help but the scope is limited, so we need to understand the challenges to ensure that they are reflected in legal considerations. There is also a need for shift in culture of understanding and efforts coming from industry to help facilitate the responsible adoption. Whilst Cobot development is still at a nascent stage, we need to move forwards in understanding the challenges and forming adequate knowledge now in order to determine what the ideal adoption outcomes should look like and prepare for the future adoption. By understanding the context and potential consequences of emerging technologies like Cobots, legal frameworks can be shaped and amended to provide adequate oversight, ensuring that these technologies are harnessed safely and responsibly.

APPENDIX

A

ADDITIONAL INFORMATION ABOUT THE STUDY

This appendix includes the additional documents in support of the Study (see Chapter 3):

- Appendix A.1 Interview Study Information Sheet
- Appendix A.2 Interview Study Privacy Notice
- Appendix A.3 Interview Study Consent Form
- Appendix A.4 Interview Study Semi-structured Interview Questions
- Appendix A.5 Interview Study Vignette is used as part of procedure to help interviewees think about what a Cobot could be.
- Appendix A.6 Interview Study Survey is sent to the participant prior to the interview to obtain participant's background Also See link here
- Appendix A.7 Example Questions from the Survey Study developed by DigiTOP Research Team

A.1 INTERVIEW STUDY INFORMATION SHEET

PROJECT INFORMATION

University of Nottingham
UK | CHINA | MALAYSIA

Date: 29/04/2019

Project: Robotics and Law PhD: Exploratory Research

School of Computer Science Ethics Reference: CS-2018-R48

Funded by: Horizon CDT, DigiTOP – EPSRC funded project

Purpose of the research. This exploratory research will be formed as a part of a PhD thesis under Horizon Centre for Doctoral Training. The purpose of this research is to gain a better understanding of current challenges with emerging technologies, in particular, collaborative robotics. Semi-structured interview will used as a research method.

Nature of participation. The participation in the research is voluntary and the research relies on the participant providing data.

Participant engagement. Participants are required to fill in a questionnaire, take part in an interview, create visual presentation of their expertise and perceptions, and allow audio/video recording of the interview.

Benefits and risks of the research. Your participation may help us understand the real-world challenges of the implementation of emerging technologies in businesses which will allow us to form adequate evaluation of current legal provisions and standards. The risks that attach to the research in terms of using your data is that it may identify you in research reports and publications.

Use of your data. The data gathered during the research will be used in supervision sessions, project meetings, and PhD reports for the purposes of the research. Please note that only the transcription of the interview will be shared in order to maintain your anonymity and protect against voice identification. The audio/video of the interview will never be shared or disclosed to the public and will only be used by the researcher of this project for the purpose of transcription. The results of the research may be disseminated, e.g., via conference workshops and presentations, publications stored online and on databases, etc.

Future use of your data. Your data may be archived and reused in future for purposes that are in the public interest, or for historical, scientific or statistical purposes. The benefits of archiving and reuse your data is to allow other researchers to explore and make further contribution to this research area. The data will be stored on University of Nottingham servers.

Procedure for withdrawal from the research. You may withdraw from the study at any time and do not have to give reasons for why you no longer want to take part. If you wish to withdraw please contact the researcher who gathered the data. If you receive no response from the researcher please contact the School of Computer Science's Ethics Committee.

Contact details of the ethics committee. If you wish to file a complaint or exercise your rights you can contact the Ethics Committee at the following address: cs-ethicsadmin@cs.nott.ac.uk

A.2 INTERVIEW STUDY PRIVACY NOTICE

PRIVACY NOTICE

University of Nottingham
UK | CHINA | MALAYSIA

The University of Nottingham is committed to protecting your personal data and informing you of your rights in relation to that data. The University will process your personal data in accordance with the General Data Protection Regulation (GDPR) and the Data Protection Act 2018 and this privacy notice is issued in accordance with GDPR Articles 13 and 14.

The University of Nottingham, University Park, Nottingham, NG7 2RD is registered as a Data Controller under the Data Protection Act 1998 (registration No. Z5654762, https://ico.org.uk/ESDWebPages/Entry/Z5654762).

The University has appointed a Data Protection Officer (DPO). The DPO's postal address is:

Data Protection Officer,
Legal Services
A5, Trent Building,
University of Nottingham,
University Park,
Nottingham
NG7 2RD

The DPO can be emailed at dpo@nottingham.ac.uk

Why we collect your personal data. We collect personal data under the terms of the University's Royal Charter in our capacity as a teaching and research body to advance education and learning. Specific purposes for data collection on this occasion are to gain a better understanding of current challenges with emerging technologies, in particular, collaborative robotics.

The legal basis for processing your personal data under GDPR. Under the General Data Protection Regulation, the University must establish a legal basis for processing your personal data and communicate this to you. The legal basis for processing your personal data on this occasion is Article 6 (1f) processing is necessary for the purposes of the legitimate interests pursued by the controller.

How long we keep your data. The University may store your data for up to 25 years and for a period of no less than 7 years after the research project finishes. The researchers who gathered or processed the data may also store the data indefinitely and reuse it in future research.

Who we share your data with. Your data may be shared with researchers from other collaborating institutions and organizations who are involved in the research. Extracts of your data may be disclosed in published works that are posted online for use by the scientific community. Your data may also be stored indefinitely by members of the researcher team and/or be stored on external data repositories (e.g., the UK Data Archive) and be further processed for archiving purposes in the public interest, or for historical, scientific or statistical purposes.

How we keep your data safe. We keep your data securely and put measures in place to safeguard it. These safeguards include: data in which participants may be identifiable will be only accessible to the experimenters and stored on a protected computer; consent forms including participant information will be stored securely; all participants will be anonymized so that no participants will be identifiable in the final analysis or report.

Your rights as a data subject. GDPR provides you, as a data subject, with a number of rights in relation to your personal data. Subject to some exemptions, you have the right to:

- withdraw your consent at any time where that is the legal basis of our processing, and in such circumstances you are not obliged to provide personal data for our research.
- object to automated decision-making, to contest the decision, and to obtain human intervention from the controller.
- access (i.e., receive a copy of) your personal data that we are processing together with information about the purposes of processing, the categories of personal data concerned, recipients/categories of recipient, retention periods, safeguards for any overseas transfers, and information about your rights.
- have inaccuracies in the personal data that we hold about you rectified and, depending on the purposes for which your data is processed, to have personal incomplete data completed
- be forgotten, i.e., to have your personal data erased where it is no longer needed, you withdraw consent and there is no other legal basis for processing your personal data, or you object to the processing and there is no overriding legitimate ground for that processing.
- in certain circumstances, request that the processing of your personal data be restricted, e.g., pending verification where you are contesting its accuracy or you have objected to the processing.
- obtain a copy of your personal data which you have provided to the University in a structured, commonly used electronic form (portability), and to object to certain processing activities such as processing based on the University's or someone else's legitimate interests, processing in the public interest or for direct marketing purposes. In the case of objections based on the latter, the University is obliged to cease processing.
- complain to the Information Commissioner's Office about the way we process your personal data.

If you require advice on exercising any of the above rights, please contact the University's data protection team: data-protection@nottingham.ac.uk

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A.3 INTERVIEW STUDY CONSENT FORM

CONSENT FORM

University of Nottingham
UK | CHINA | MALAYSIA

Date: 29/04/2019

Project: Robotics and Law PhD: Exploratory Research

School of Computer Science Ethics Reference: CS-2018-R48

Funded by: Horizon CDT, DigiTOP – EPSRC funded project

Please tick the appropriate boxes	**Yes**	**No**
1. Taking part in the study		
a) I have read and understood the project information sheet dated 29/04/2019, or it has been read to me. I have been able to ask questions about the study and my questions have been answered satisfactorily.	☐	☐
b) I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time by contacting natalie.leesakul@nottingham.ac.uk, without having to give a reason. If I withdraw I understand that my individual data will be deleted.	☐	☐
c) I understand that taking part in the study requires me to provide data and that this will involve fill in a questionnaire and participate in an interview.	☐	☐
2. Use of my data in the study		
a) I understand that my name will not be publicly associated with any data	☐	☐
b) I understand that data which can identify me will not be shared beyond the project team.	☐	☐
c) I agree that the data provided by me may be used for the following purposes:		
– Presentation and discussion of the project and its results in research activities (e.g., in supervision sessions, project meetings, conferences).	☐	☐
– Publications and reports describing the project and its results.	☐	☐
– Dissemination of the project and its results, including publication of data on web pages and databases.	☐	☐
d) I give permission for my words to be quoted for the purposes described above.	☐	☐
3. Reuse of my data		
a) I give permission for the data that I provide to be reused for the sole purposes of future research and learning.	☐	☐
b) I understand and agree that this may involve depositing my anonymized processed data in a data repository, which may be accessed by other researchers.	☐	☐
4. Security of my data		

a) I understand that safeguards will be put in place to protect my identity and my data during the research, and if my data is kept for future use. ☐ ☐

b) I confirm that a written copy of these safeguards has been given to me in the University's privacy notice, and that they have been described to me and are acceptable to me. ☐ ☐

c) I understand that no computer system is completely secure and that there is a risk that a third party could obtain a copy of my data. ☐ ☐

5. Copyright

a) I give permission for data gathered during this project to be used, copied, excerpted, annotated, displayed and distributed for the purposes to which I have consented. ☐ ☐

b) I wish to be publicly identified as the creator of the following works: audio/video recordings, drawings, and any other material I produced or co-produced during the study. ☐ ☐

6. Signatures (sign as appropriate)

Click or tap here to enter text. Click or tap here to enter text. Click or tap here to enter text.

Name of participant (IN CAPITALS) Signature Date

If applicable:

For participants unable to sign their name, mark the box instead of signing

I have witnessed the accurate reading of the consent form with the participant and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

Name of witness (IN CAPITALS) Signature Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

NATALIE LEESAKUL Signature Date

7. Researcher's contact details

Name: Natalie Leesakul

Phone: [redacted]

Email: natalie.leesakul@nottingham.ac.uk

A.4 INTERVIEW STUDY SEMI-STRUCTURED INTERVIEW QUESTIONS

Academic Researchers:

- Background/Expertise
  - What projects are you involved in?
  - How do you get involved or how are you involved in the project?
- General
  - What are the different emerging technologies in your opinion?
  - What are the challenges with such technologies?
  - What do you think is the role of lawyers and ethicists in implementing or designing technologies?

  If participant has worked with lawyers and ethicists, ask the followings:

  - How did you get them involved?
  - Do you think it's been worthwhile?
  - What techniques or tools did you use to collaborate with the lawyers or what tools did the lawyers they provide you with?

Corporate Lawyers:

- Background/Expertise
  - Have you had any experience dealing with implementing new technologies in your current or past organization?
- General If the participant answers yes, ask the followings
  - Were there any challenges?
  - If it had to be done again, would you change something in the way it was implemented?

  If the participant answers no, ask the followings:

  - What are the different emerging technologies in your opinion?
  - What are the legal challenges and risks for the implementation such technologies?
  - How would you mitigate the risks?

Technologists/Designers:

- Background/Expertise
  - What projects are you involved in?
- General
  - What are the different emerging technologies in your opinion?
  - What are the challenges with such technologies?
  - What do you think is the role of lawyers and ethicists in implementing or designing technologies?

    If the participant answers no, ask the followings
  - What techniques or tools did you use to collaborate with the lawyers or what tools did the lawyers they provide you with?

All Participants: Provide brief introduction into cobots

- Have you worked with cobots before?
- If yes, ask this – What is your opinion on cobots?
- In your opinion (give the description if they have not worked with cobots before)
- What are the legal challenges with collaborative robotics or robotics in general?
- What are the ethical challenges with collaborative robotics or robotics in general?
- What are the social challenges with collaborative robotics or robotics in general?

A.5 INTERVIEW STUDY VIGNETTE

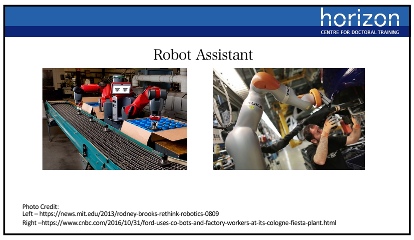
7/2,

CoBots are designed to work in direct collaboration with a human in a dynamic environment.

1

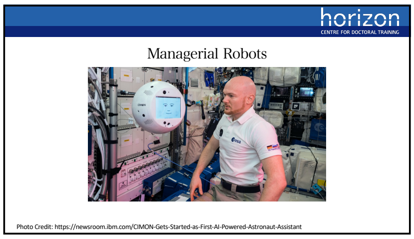
- Function like an **AI 'colleague'** and can interact directly and safely with humans
- Assist human workers in a large **diversity of tasks**
- **Understand** its collaborator's intentions and **communicate** its own
- Predict human actions
- **Decide** when to lead the task or when to follow the collaborator by rapidly **adapting** to the collaborator's actions or requirements

2



3

4



5

A.6 interview study survey

Robotics and the Law: Exploratory Research

* Required

1. What is your area of expertise? *

Enter your answer

2. What is your role in the organization? *

Enter your answer

3. How many years of experience do you have in this role?

Enter your answer

4. How many years (if any) of experience do you have in dealing with smart technologies i.e. robotics, AI, IoT, etc.? *

Enter your answer

5. In relation to question 4: What types of smart technologies have you dealt with?

Enter your answer

6. Have you ever done any work with robotics? *

Enter your answer

7. How familiar are you with collaborative robotics (also known as “cobot”)? *

- Not familiar at all (I have never heard of cobot)
- Slightly familiar (have heard of it but don’t know what it does)
- Somewhat familiar (I have a broad understanding of what it is and what it can do)
- Extremely familiar (I have extensive knowledge on cobots)

8. In your opinion, how would you define collaborative robotics?

Enter your answer

A.7 SURVEY STUDY QUESTION EXAMPLES

Example Questions from the Survey Study developed by DigiTOP Research Team

Digital Manufacturing Technologies Survey - FINAL

Start of Block: Introduction

Industries in the UK are going through a digital transformation, investing in high-end digital manufacturing technologies (DMTs) to increase their productivity and remain competitive. Digital manufacturing refers to the use of smart, digital, autonomous, and intelligent technologies within the manufacturing sector. These technologies include robotics, sensor technologies, Virtual and Augmented Reality, distributed networking technologies, additive manufacturing, Artificial Intelligence and analytics, simulation, and cloud computing.

We are interested in factors that influence the acceptance and adoption of digital manufacturing technologies. Therefore, this questionnaire has been developed to gather the opinions and experiences of people working in manufacturing.

This research is being conducted by Cranfield University where all data will be collected and stored securely in full compliance with the Data Protection Act 2018 and with the university's own Research Ethics Policy. Data will only be used for the research activities outlined above, and only overall results will be reported. It will be retained for a limited period (maximum ten years) after which time it will be destroyed.

Your identity is not required; we will ask you to provide a few personal details just so that we can group data into basic categories (e.g. age, gender) but this is completely optional. You have the right to stop and withdraw from the questionnaire at any point without any justification.

Q26 How much interaction did you have with the technology producers during the following 3 phases?

	A great deal	A lot	A moderate amount	A little	None at all
During the design/development phase	○	○	○	○	○
During the installation/start-up phase	○	○	○	○	○
During the normal operation phase	○	○	○	○	○

Q28 How did the following issues change for the people working directly with the newly introduced digital manufacturing technology?

	Decreased	No change	Increased
	0 1 2 3	4 5 6	7 8 9 10
Skills			
Fatigue			
Interesting tasks			
Physical workload			
Mental workload			
Autonomy/control			
Job security			
Surveillance and performance monitoring			
Stress or anxiety			
Job fulfilment			
Monotony of the job			
Safety concerns			
Occupational diseases (for instance noise-induced hearing loss)			
Interaction with colleagues			

B

ADDITIONAL INFORMATION ON THE STUDY FINDINGS

This appendix includes the additional information from the Study analysis (see Chapter 3):

- Appendix B.1 Interview Study Participants
- Appendix B.2 An illustration of selections of thematic analysis codes, descriptions, and examples
- Appendix B.3 The full quote explaining the the role of data protection regulations and other legal implications

B.1 INTERVIEW STUDY PARTICIPANTS

Unique Codename and Classification	Role in the Organisation	Area of Expertise	Years of Experience in the Field of Expertise	Years of Experience in Dealing with Smart Technologies	Types of Smart Technologies
P1T	Deputy Director	Robotics and autonomous systems	30	25	Human Robot Interaction
P2M	Quality Director	Automotive industry—quality control	15	5	Industrial robots, Cobots
P3T	Chief Technology Officer	Quality management, software, artificial intelligence, standards development	20	4	Machine learning/AI
P4C	Founder and Director	Privacy, data protection, public policy	15	15	Industrial robotics, consumer IoT
P5R	Senior Researcher	Human centred computing	4	4	Ethics, responsible innovation and governance of robotics, AI, IoT
P6C	Consultant	Digital technologies, social responsibility, sustainability, and ethics; organisational behaviour; standardization	39	20	Most of the smart technologies
P7L	Research and teaching	Law and technology	25	25	Legal expert systems; machine translation, robotics, AI
P8L	Partner	Law and connected	23	5	Transport tech, CAVs

		autonomous vehicles			
P9C	Director	Connected and automated vehicles, Technology commercialisation	5	5	Connected and automated vehicles
P10C	Founder and Owner	Connected and autonomous vehicles infrastructure	30+	10	Traffic and transportation systems, LiDAR and camera technology on vehicles, robot concept
P11L	Director (senior lawyer)	Law and connected autonomous vehicles, specifically transport regulation	18	5-6	Aspects of robotics, HMIs, AI, IoT, connected and autonomous vehicles
P12L	Senior Associate	Law, technology, and data	8	8	From a legal perspective: AI, IoT, connected and automated vehicles
P13L	Professor	Law and technology	7	10	Robots, AI, AR, VR, IoT
P14M	Innovation Manager	Manufacturing	20	3	Automated guided vehicles, robotic arms
P15M	Projects	Automation	30+	30+	Robotics, vision systems, sensing systems

B.2 DESCRIPTION OF CODE (IN DETAIL)

Theme	Code	Description	Example
Adoption of new technology	Acceptance of new technology	Elements that influence people to accept or not accept new technology (user perspective)	*P14M: "We have got various systems and those operations automated with robots. People tend to take those quite, quite well. Jobs that are boring and monotonous then people will choose not to do to be fair. And particularly it's cold in our factories."*
Adoption of new technology	Change management	Approaches that can help prepare, support organisations in adopting new technology	*P2M: "I will say in our activity, we have no issue with that. In fact, nobody has gotten fired. And this is why it's easy for us just to explain what we want to do and what are the reasons such as our company will be more profitable. They are not afraid that they will be fired."*
Trust	Trust	Key contributions of forming trust in new technology and robots	*P5R: "So then you have issues around explaining ability, should we try to create tools that are explainable to people, and if we can't explain them, then should we be using them? And I think that's kind of a question that comes up with about automated decision making. So transparency is a big issue in relation to trust."*
Data and privacy	Data and privacy	Different aspects surrounding the role of data and privacy in technology design and adoption	*P4C: "Anything that brings more sensors, cameras and microphones close to the human person has a privacy challenge because what you are doing is you are starting to gather more and more types of data. As you do that, that data is radioactive,*

			that data is very revealing and intimate."
Due Diligence	Due diligence must be performed	Discussion and challenges around due diligence that should be performed by designer and the implementor in order to ensure the integrity of the technology, in particular robotics	*P6 Consultant: "I think that there is a huge gap between realistic expectations of ethical behavior, and the willingness of developers to assume their responsibilities on behalf of stakeholders. So I think number one, there isn't enough stakeholder involvement. Number two, there's too much of a benefits based approach as opposed to a risk mitigation approach and a harm based approach."* *P2 Manufacturer: "we have checked all the risks are really manageable for the current cobot technology."* *P12 Lawyer: "So for many of the products I see on a daily basis, there is a degree of reliability on the software vendor to have done their due diligence on the products that they're launching. For my perspective is the due diligence on the products as their compliance to the customer environment."*
Regulatory	Regulatory challenges	Concerns around the challenges of current legal system in relation to new technology (including robotics) and the need for new regulatory regimes	*P7 Lawyer: "We have the tendency to use technology that works sufficiently well and then expect from humans to work around this. That works for the average human… if you are using voice recognition to enable the Cobots to interact with you, what*

			happens to people like me who speak with a strong foreign accent or all immigrants [or] a facial disfigurement, which doesn't enable them to speak...So we have a whole set of questions of equality law, disability law that intersects here with labor law again and how these line up in the workplace." *P11 Lawyer: "Apparently they have robotic systems and the safety of work regulations, they exist, and they already provide a framework for that. Interestingly, the mitigation for a lot of it is that there's basically separation between robot and human."* *P15 Manufacturer: "I think the regulators are way behind where technology is. And the reality of that is actually what is causing us problems because going back to the unknowns and the Cobots and how things work. There is no case law. So there's nothing there. There's nothing stated, there's so much of it that sitting in common sense and would I be prepared to risk doing that?"*
Design	Design of robot	The characteristics of robots and design process that can help with the adoption of this technology	*P1 Technologist: "I think that there are a whole pile of technological problems or challenges to overcome… not to the same degree that humans have, but clearly, that ability to be*

more dexterous in manipulating objects and the ability to be able to cope with the fact that the situation isn't always exactly the same."

P3 Technologist: "There is a very strong argument that in order for people to trust these kinds of robots, there needs to be a way to understand why it did what it just did. And that might be a button on his head that you press that explain what it just did and why"

P6 Consultant: "what can't happen is giving any machine true autonomy. And we can give automation and we can automate to the nth degree but not autonomy. And so I think it's a misnomer to talk about autonomous systems, because I think it implies that it's feasible and desirable. And I think even if it's feasible, it's not desirable."

B.3 ADDITIONAL QUOTE

Full quote from Section 3.3.4.2 explaining the the role of data protection regulations and other legal implications by P7L, Law and Technology Professor

> *"The GDPR doesn't help because at least two articles where they conflate these two, data portability for instances, my opinion, not a data protection principle but a copyright principle. Data Protection is a common good public law concept. But there is also a question of data ownership and knowledge ownership. So, to what extent can I be forced to enable a robot to learn from me, to acquire my skills, and then potentially make me unemployed? To what extent is this type of knowledge something for which I should get compensation? What are the labor law implications in that sort of environment as a part of my contract to collaborate here? So for instance, I work with a cobot in an industrial environment. The robot listens to my voice to get speech commands. As a consequence of that, it will process also personal data about me... I tell the robot 'I'm right in front of you.' And so a data point is created that says, 'Rob was in front of the robot on the 12th of July, in that specific place.' So that's data protection law that comes in. And Data Protection law very clearly would say, I think this is a legitimate interest of the data controller – in order to fulfill my job and in order to work in that environment, I have to let that robot know that I'm there just in the same way as my co workers, so no problem here from a data protection perspective. Assume that this robot takes the snippets of my voice and uses them as feedback and creates a better voice recognition as a result. I have copyright in what I said. Through an employment contract, my employer has the copyright for the work that I create but this is a suddenly now really becoming copyright law issues. So, I might say, 'yes, you're allowed to processes for the purpose of workplace safety*

and doing my job. But at the moment you gain an additional commercial value out of my speech and to get re-compensated as that is not part of my employment contract, that is going above and beyond what I'm obligated to do.' There you can see, even though this is okay, from a data protection perspective, there is still a potential alternative obstacle here. Some may say this is protected by copyright and even if under employment law, my employer has the right to use this, maybe even to commercially exploited, there are still the moral rights of the author. There're people who are now so worried about using copyright and IP law in general. IP right matters here on its own terms, and it might prevent use of data that is permissible under Data Protection Law."

— P7L, Law and Technology Professor

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