Industry 4.0: the impact of strategic leadership behaviour on organisational response to the adoption of technological innovation.

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Industry 4.0: the impact of strategic leadership behaviour on organisational response to the adoption of technological innovation

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Abstract

The rapid development and cross interaction between emerging technologies is called Industry 4.0, and it is being called the Fourth Industrial Revolution. Organisational leaders are seeking to understand how to lead their firms to benefit from the opportunities that these technologies offer, as well as mitigating against the threats that the technologies could pose. This thesis aims to examine how Industry 4.0 and strategic leadership behaviours are intersecting and influencing each other. This study forms part of the requirement for completion of a Doctorate of Business Administration, a professional doctorate that was undertaken whilst the researcher was in full time employment in a leadership role. Partially influenced by professional practice, the research philosophy that underpins the study is pragmatic.

Data collection was completed using semi-structured qualitative interviews. Data analysis included inductive and deductive thematic analysis to re-signify strategic leadership behaviour in the context of Industry 4.0. Yukl's 2012 hierarchal behavioural taxonomy was selected as the most appropriate framework to connect to existing literature on leadership behaviour.

The primary finding is the display of knowledge management behaviours by strategic organisational leaders. This thesis recommends significant changes to Yukl's behavioural taxonomy by the addition of a metacategory called 'knowledge-based behaviours', and removal of 'externally focused behaviours' metacategory. This metacategory is partially populated by previously identified behaviours; networking, external monitoring, representing, and facilitating collective learning. The objectives behind these behaviours are revised in line with the findings of this study. Additionally, a novel behaviour of critical evaluation is also included in the knowledge-based behaviour metacategory. Secondary findings include the revising the objectives of existing behaviours, as well as the identification of another novel behaviour 'mission matching'. Finally, the study provides evidence that the enablers and challenges of Industry 4.0 adoption previously theoretically identified in literature are broadly applicable; however, there is divergence on which factors have the most impact. This study also identified additional factors such as scepticism and the lack of a clear definition of Industry 4.0 impeding collective learning behaviours in organisations. This thesis proposes an updated definition of Industry 4.0, as well as a conceptual framework to assist with categorising technologies.

Keywords: Industry 4.0, Leadership behaviour, Innovation, Technology, Knowledge Management

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Chapter One: Introduction

In 2013, the German government introduced the concept of Industry 4.0 to Hannover fair as a core pillar underpinning the country's industrial strategy. Industry 4.0 is umbrella terminology, used to refer to an evolving range of technologies and their impact. By defining this concept, the German government acknowledged the increasing breadth of new technologies and acknowledged the impact and value that the technologies could bring. The creation of a macro lens to view the development through also allowed the scope of the lens to increase as the technologies continued to develop. In 2013, the key technologies referenced were data mining techniques such as Big Data, machine learning and the 'Internet of Things' (IoT), also known as the 'Industrial Internet of Things' (IIoT). (Dohale & Kumar, 2018)' Since 2013, the use of blockchains and novel applications of artificial intelligence have increased and are also recognised under the purview of Industry 4.0. In addition to the breadth of the technologies, attention is also given to how the technologies intersect with each other and existing institutional structures. This compounding of technologies and applications gives a reinforcing system of technology development that exponentially increases their impact (Schwab, 2017). Despite the challenges of adapting to this pace of development, Industry 4.0 technologies are recognised as containing the potential to revolutionise the way that organisations create and derive value. By bringing the technologies under one umbrella term 'Industry 4.0', the impact could be viewed as the fourth industrial revolution. Consequently, existing firms will rely on their leaders to identify and navigate the opportunities and threats posed by these technologies.

As the second and third industrial revolutions progressed, the literature on leadership behaviour showed corresponding themes in predominant leadership behaviours. As a response to the second industrial revolution, the school of scientific management emerged, with a focus of efficient task completion via the development of production lines (Drury, 1918). The organisation of work into discrete units to be completed in a standardised way for maximum efficiency was echoed by the prevalence of task-based leadership behaviours (Stogdill & Shartle, 1948) (Katz, et al., 1950). The third Industrial Revolution saw the introduction of computing power into organisations to further increase the pace of value production. Leadership behaviours that supported effective change in the organisation were viewed with increasing importance throughout this time (Arvonen & Ekvall, 1991). It is therefore timely and prudent to evaluate how leaders are responding to the impact of Industry 4.0. This research project was initiated to examine how Industry 4.0 and strategic leadership behaviours are intersecting and influencing each other. This thesis analyses the behaviours that leaders are demonstrating as they work their way through this challenge.

Research Aims and Objectives

The aim of the research study is to answer the question ''How do strategic leadership behaviours intersect with Industry 4.0?''. In support of this aim, a review of the literature was completed to identify and define leadership behaviours. Data collection achieved via semi structured, descriptive interviews with leaders in organisations was analysed for evidence of these behaviours; data was further analysed for the presence of behaviours that were not present in the literature review. In addition, a review of the literature available on Industry 4.0 identified the theoretically anticipated

enablers and challenges that leaders would need to respond to as part of their response to Industry 4.0. Data was analysed for the presence of these factors, as well as any previously undocumented considerations. Therefore, the aim of this thesis was met by the completion of the following objectives:

1. Evaluate to what extent previously identified leadership behaviours are present in strategic leader responses to Industry 4.0
2. Identify if any uncategorised behaviours are being exhibited in strategic leader responses to Industry 4.0
3. Evaluate the behaviour demonstrated by strategic leaders in response to Industry 4.0 in comparison to the enablers and inhibitors identified in the literature to date
4. Identify any additional enablers or inhibitors that are impacting strategic leader behaviours in the Industry 4.0 context

By answering the research question, this thesis contributes to knowledge by connecting the literature on leadership behaviour to the literature on Industry 4.0. This link provides a new way of framing leadership behaviour in the context of a contemporary challenge, allowing researchers and practitioners to identify further areas of research and practice development.

Overview of Supporting Theory

Initial leadership behaviour studies conducted by Michigan University and Ohio State University identified two categories of leadership behaviour, which have come to be known as 'task-orientated' and 'relational' behaviours (Katz, et al., 1950) (Stogdill & Shartle, 1948). Throughout the following decades, leadership researchers sought to understand how leadership behaviours interacted with each other to impact a leaders' effectiveness, as well as any moderating influence of the situation that the behaviours are demonstrated in (A.W. Halpin, 1957) (House, 1977) (Fieldler, 1964) (Misumi & Peterson, 1985) (Moulton & Blake, 1964). Attention was also given to the conceptualisation of patterns of leadership behaviour as leadership styles; the formation of transformational and charismatic leadership styles by Bass (1996) and Avolio (1999) allowed change-based behaviours to become implicitly integrated into the body of knowledge, the presence of which was later empirically proven by Arvonen and Ekvall (Arvonen & Ekvall, 1991) (Avolio, 1999) (Bass, 1996).

The complexity of the body of knowledge on leadership behaviour has led to some leading theorists to develop behavioural taxonomies; the most notable of these are those developed by Yukl and Fleischman respectively (Yukl, et al., 2002) (Yukl, 2012) (Fleishman, et al., 1991). The hierarchal behavioural taxonomy developed by Yukl was subject to a meta-analysis conducted by Borgmann et al and found to be empirically valid (Borgmann, et al., 2016). Therefore, this research study chose to reinterpret Yukl's taxonomy in the context of Industry 4.0.

Research Study Relationship to Theory

The creation of a research aim and associated objectives requires reflection on how to position the research aim in relation to existing theories within the body of knowledge. The consideration of how to connect to existing theory is fundamental to making meaningful contributions as researchers 'use

theory to make distinctions and order our understanding of organizational phenomena, to form interpretations and explanations, or to develop informative accounts for students, practitioners, and other potential stakeholders' (Cornelissen, et al., 2021, p. 2).

A primary step in theory understanding is posited as 'conceptualisation' – the act of framing a phenomenon within a resource. In this thesis, the phenomenon is 'leadership behaviours' framed within the primary context of 'Industry 4.0'. Once conceptualised, the act of theorising can be divided into disparate approaches, based on how the researcher seeks to connect the phenomenon to the resource. Cornelissen et al name these approaches as explanatory, interpretative and emancipatory (Cornelissen, et al., 2021). Briefly, explanatory theorising has the focus of identifying processes and frameworks and requires the underlying assumption that there is a repeatable, generalisable pattern to be found. Interpretative theorising does not share the same assumption that there is an underlying process to be found, and instead seeks meaningful contributions by recontextualizing existing knowledge in a way that is socially or historically important. Finally, emancipatory approaches to theorizing aim to challenge existing theories by highlighting where they fall short of an ideal, values driven theory. This approach often centres the researcher as 'positioned and active' (Deetz, 1996, p. 197) in the pursuit of emancipation rather than solely focuses on their membership of a research community.

Within this thesis, the approach taken to theorizing aligns most closely with an interpretative approach. The study recontextualises the existing knowledge of leadership behaviours within the socially significant fourth industrial revolution. This reflects the statement made by Cornelissen et al 'interpretive theorizing encourages researchers to introduce new topics that better reflect and capture our present-day experiences of organizations' (Cornelissen, et al., 2021, p. 10) Referred to as 're-signifying' (Cornelissen, et al., 2021, p. 10), reconceptualising leadership behaviours within the context of Industry 4.0 allows the researcher to introduce knowledge from leadership and organisational behaviour scholars to analysis of Industry 4.0 technology applications and infrastructure. This intersectionality of bodies of knowledge provokes a fresh outlook on previously established theory. However, interpretative theorising is recognised as challenging; the limitations of the assumptions underpinning previous theory must be acknowledged and addressed in parallel to the development of deeper insight into the phenomenon (Cornelissen, et al., 2021).

To adequately address this challenge, consideration must be given to the formulation of the research objectives. Within management studies, a recognised concern is the predominance of 'gap-spotting' as a foundational underpinning of research objectives (Alvesson & Sandberg, 2011). Locke and Golden-Biddle (2007) found that many qualitative management studies positioned their contributions by 'arguing that existing literature was either incomplete or had overlooked an important perspective and that those were gaps that needed to be filled' (Golden-Biddle & Locke, 2007) (Alvesson & Sandberg, 2011, p. 249). This emphasis on 'footnote-on-footnote research' (Daft & Lewin, 1990, p. 1) comes at the expense of the creation of high impact contributions. High impact, novel theory development is more likely to occur when the assumptions underpinning accepted theory are challenged, through a methodology referred to as 'problematisation.' Alvesson and Sandberg posit that problematisation methodology use is inhibited by the political context that

management studies are conducted within. There is recognition that there is a professional risk associated with challenging popular theories that may disrupt the professional and personal networks that researchers need to maintain to progress in their career. As the researcher of this study is predominantly a leadership practitioner, this is less of a concern in this thesis.

Furthermore, a balance must be considered between the benefits offered by 'problematization' of generating novel theory against the risk of further fragmenting the literature on leadership behaviour. Contemporary leading theorists in this field have highlighted the challenges in resolving the many available concepts of leadership, behaviour, styles, and traits into a meaningful and coherent body of knowledge that retains its relevance for practitioners and other stakeholders (Avolio, 2007) (Yukl, 2009). The introduction of interesting, meaningful theory must have a robust methodological research design to compensate for the risk of further fragmentation (Yukl, 2009).

The objectives of this study are defined in such a way as to aim to maintain connections to existing theory within the body of knowledge, whilst still challenging the available theories underpinning leadership behaviour against the context of Industry 4.0. The research objectives are

1. Evaluate to what extent previously identified leadership behaviours are present in strategic leader responses to Industry 4.0
2. Identify if any uncategorised behaviours are being exhibited in strategic leader responses to Industry 4.0
3. Evaluate the behaviour demonstrated by strategic leaders in response to Industry 4.0 in comparison to the enablers and inhibitors identified in the literature to date
4. Identify any additional enablers or inhibitors that are impacting strategic leader behaviours in the Industry 4.0 context

Objectives one and three use the operative word 'evaluate' to highlight the challenge to existing theory that this analysis will aim to achieve. By comparing the behaviours demonstrated in data to both the existing leadership behaviour theory and Industry 4.0 theory, a conceptual bridge can be built between these two bodies of knowledge. The drawing out of a connection allows space for the development of new theory that reinforces deeper insight back into the two bodies of knowledge. Objectives two and four allow the researcher to identify gaps in the literature, induced from data rather than inferred from literature. By having objectives underpinned by an interpretative theorising, problematised methodology, the context of Industry 4.0 can be used to challenge the assumptions made in leadership behaviour theory. Any fragmentation introduced by this challenge can be somewhat balance by having objectives that aim to answer the gaps between the fragmentation, or to provide further direction for future research.

Research Approach

As stated in the relationship to theory section of this chapter, the research objectives have been positioned in relation to theory to support the development of impactful novel theory whilst minimising disconnect from existing theory. The challenge to theory is chartered by analysing data through the lens of existing theory, a deductive approach. The connection to existing theory is maintained by analysing data for further insight in relation to existing theory, an inductive approach.

This combination of inductive and deductive analysis is referred to as an overall pragmatic approach and reflects the researcher's philosophy of seeking maximum impact without a particular focus on the purity of the underpinning methodology. This philosophy is admittedly influenced by the researcher's position as a leadership practitioner in industry.

The re-signification of leadership behaviour in the context of Industry 4.0 supports the study being positioned as exploratory. The phenomenon within the study, leadership behaviour, is a concept that becomes observable via the experience of others. The subjective nature of the phenomenon endorses the ontological foundation of the study as interpretivist, as data is subject to the reality of the participants as well as the researcher. The interpretivist approach is further embedded into the study by the analysis of data by the researcher, who further applies their perception as they determine which data is of significance. The values and worldview which contribute to this perception underpin the axiological and epistemological influences on the study, which are explored further in the methodology chapter.

Research Relevance

An analysis of the search term 'Industry 4.0' via Google Trends shows the increasing popularity of the concept, and a regional breakdown highlights its global reach. Further investigation of who is discussing Industry 4.0 highlights the increasing relevance that a wide range of stakeholders are recognising in Industry 4.0.

Figure 1 Figure showing trend over time of google searches containing Industry 4.0

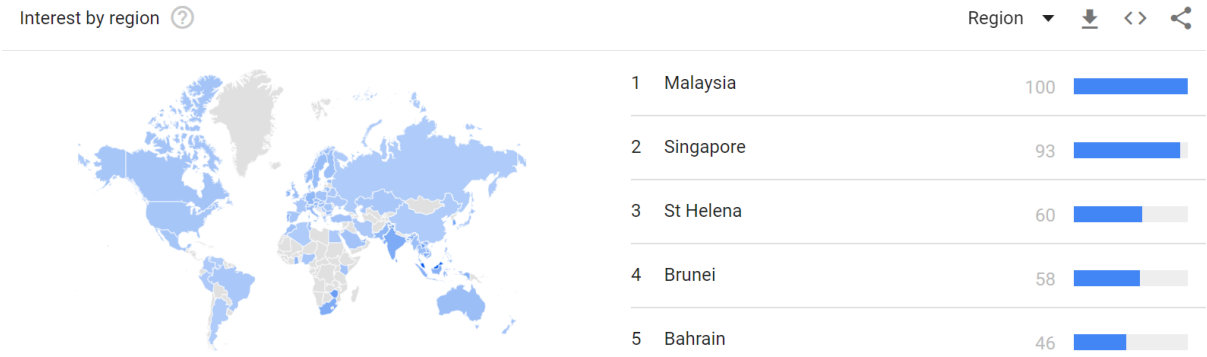

Figure 2 Geographical representation of locations searching for Industry 4.0 as a reference term

The response to Industry 4.0, and concern for its impact on organisations, can be evidenced by the abundance of industry commentary on this subject. In 2017, the World Economic Forum created the 'Centre for the Fourth Industrial Revolution Network' with the aim to ensure that the impact of the Industry 4.0 technologies contributes positively to societies (World Economic Forum, 2017) . McKinsey, Deloitte and Boston Consulting Group have all published white papers and articles that highlight the profound impact that Industry 4.0 is predicted to have on organisations, even accounting for the impact of the COVID-19 pandemic (McKinsey, 2020) (Deloitte, 2021) (Boston Consulting Group, 2021) .

Deloitte states that 'executives are particularly focused on societal impact and workforce development as two critical components of their future success. At the same time, roadblocks appear to be limiting the development of effective strategies, and organizations continue to shy away from bold technology investments that will drive innovation and disruption' (Deloitte Insights, 2019)

Governments have also responded via policy: the German government launched Industrie 4.0 (Federal Ministry for Economic Affairs and Energy, 2019); France and Italy have developed Factory of the Future initiatives (European Parliament, 2015) and the UK government set 'Four Grand Challenges' to 'seize the opportunities presented by the Fourth Industrial Revolution' (HM Government, 2017, p. 32). This has been supported in the creation of Catapult centres as well as bureaucratic support from the recently created Office for Artificial Intelligence. Although the Grand Challenges have been superseded by the 'Building Back Better' policy, Industry 4.0 relevance remains as the UK government remains committed to 'building on our advantages in foundational technologies like AI, quantum computing and digital twins, including through the National Data Strategy and upcoming Digital Strategy' (HM Government, 2021, p. 54).

Within academia, the annual count of publications referring to Industry 4.0 increased from 92 in 2013 to 5,299 in 2020. Within this count of literature, publications connecting Industry 4.0 to Management and Leadership increased from 2 in 2013 to 771 in 2020 (Dimensions, 2021). A 2019 paper remarked that 'the ambition to exploit Industry 4.0 technologies is high among top management; the barriers were considered less important than the motives' (Halse & Jæger, 2019, p. 140). The literature on Industry 4.0 calls for further research that moves the focus away from specific applications of technology to a comprehensive overview of how organisations and their leaders can respond (Caputo, et al., 2016).

The high level of focus that academia and industry practitioners place on Industry 4.0 technologies, and the management practices required to leverage opportunities and overcome challenges, demonstrates that this thesis is highly relevant to knowledge and practice.

Overview of Thesis Structure

This thesis opens by reporting on the literature review that was undertaken in support of the research aim and objectives. The literature review considered research completed on leadership behaviours, traits and styles and identifies taxonomies of leadership behaviours that have been

proposed as foundations for future research. The literature review also covered leadership adjacent studies on innovation management and strategy development in response to technological changes. Literature on Industry 4.0 and associated technologies is discussed, and the factors affecting organisational implementation of Industry 4.0 technologies are identified. Finally, literature that anticipates specific leadership challenges in Industry 4.0 is analysed.

Following the literature review, the research methodology chapter explains the positioning and framing of this research study in relation to the body of knowledge available on leadership behaviours and Industry 4.0. The methodology chapter highlights the philosophical assumptions made by the researcher in the design of the study and discusses the influence of the researcher's experience in practice on their perspective of leadership behaviour. The chapter also explains changes made to the research study as a result of the pilot study undertaken. An introduction to the study participants is made through pen portraits, and the researcher's reflection on their experience through data collection.

The third chapter in this thesis documents data collected throughout the study and the findings identified by the researcher. This chapter is structured into five sections; the first four sections correspond with an individual research objective. The fifth section documents a cross analysis of the findings in the previous four sections.

Finally, the thesis concludes by highlighting the key findings of the study and recommendations for future research. Consideration on the extent of the contribution to knowledge and to practice is also given.

Chapter Two: Literature Review

Introduction to Literature Review

This chapter identifies areas of literature that have relevance to the field of leadership behaviour, and Industry 4.0 or associated technologies. These areas have been identified as relevant to supporting the desired outcome of this research study; to evaluate how strategic leadership behaviours intersect with Industry 4.0.

This literature review starts with an overview of the seminal studies that provide the foundation for contemporary models and theories for defining leadership, and leadership behaviour. The review then moves to literature that connects leadership behaviour with the strategic environment, and innovation. A review of leadership behaviours in relation to knowledge management follows. The review then moves on to an evaluation of pertinent literature on the fourth industrial revolution, including a focus on the key technologies that are proposed to underpin Industry 4.0. This review then considers literature that connects leadership behaviours with the adoption and utilisation of Industry 4.0 technologies. The review then moves to discuss the enablers and inhibitors of adoption and utilisation of Industry 4.0 as identified in the available literature. This chapter concludes by identifying the key literature that the researcher used to conceptualise the study and the specific gap in knowledge that the research study aims to address.

Defining Leadership

The definition of leadership, and therefore a leader, has been widely discussed in the literature. Different definitions offer particular focus on the different elements of effective leadership. Early definitions focused on the goals of leadership. In one of the earlier definitions, Stogdill and Shartle (1948) proposed the definition of leadership as 'a process of interaction between persons who are participating in goal oriented group activities' (Stogdill & Shartle, 1948, p. 287). Rather than the process view, Josefowitz (1980) suggested that, in an organization, leaders' responsibilities could be categorized under four functions: planning, controlling, organizing-coordinating and directing-motivating (Josefowitz, 1980) and so offers a multidimensional definition of leadership. Whereas Mulder (1987) suggests that purposefulness, directing the course of action, decision-making, self-confidence, risk-taking, learning, leadership of people, communication, flexibility, generating creativity, etc., are the qualities in which leaders must score high (Mulder, 1987). Lord and Maher (1993) based their definition of leadership on the view of others, simply stating that 'leadership [is] the process of being perceived by others as a leader' (Maher & Lord, 1993, p. 11). Drucker (2001) combined the two themes of perception and action to propose that 'leadership rests on being able to something others cannot do at all or find difficult to do even poorly' (Drucker, 2001, p. 118). This was further refined by Yukl (2009), who offered the definition of leadership as '… the process of influencing others to understand and agree about what needs to be done and how to do it, and the process of facilitating individual and collective efforts to accomplish shared goals' (Yukl, 2009, p. 8). Due to its derived development, this definition of leadership will be used throughout this study.

Leadership Behaviours

The examination of leadership behaviour began in the 1950's, when criticisms of trait theory began to be addressed. Studies conducted by Michigan University and Ohio State University established a two-factor axis of leadership behaviour, which have come to be known as 'task-orientated' and 'relational' behaviours (Katz, et al., 1950) (Stogdill & Shartle, 1948). As the Ohio State study concluded, 'leadership is not a unitary human trait, but is rather a function of a complex set of individual, group, and organizational factors in interaction. Leadership must, therefore, be studied as a relationship between persons, and as an aspect of organizational activities, structures, and goals. A comprehensive formulation of the problem is required in order to take these factors into account' (Stogdill & Shartle, 1948, p. 286). This quote remains relevant to today's leadership scholars: by conducting research into leadership behaviour, the impact of leadership behaviours can be more clearly understood, and practitioners are able to apply the appropriate behaviours to match their goals. This ultimately leads to an increase in efficiency and productivity, and increased value for organisations. Additionally, there is evidence that leadership behaviour is more proximal to the act of effective leadership. A meta-analysis conducted showed that behaviours accounted for 20-70% of variance in leadership effectiveness (Derue, 2011).

Leadership behaviour research built on the initial identification of relation and task-orientated behaviour to investigate the influencing process, the role of the situation and the impact of the leader's goals, and effectiveness criteria. Yukl states that ''an important objective in much of the leadership research has been to identify aspects of behaviour that explain leader influence on the performance of a team, work unit, or organization.'' (Yukl, 2012, p. 66).

Key findings in this area have been the establishment of the range of factors that interact with leadership behaviour and effectiveness. These factors are

- Research into leadership styles observed the increasing presence of leaders that displayed behaviours outside of task-orientated and relational categories, in a style referred to as transformational or charismatic leadership (Conger & Kanungo, 1987) (Burns, 1978). Later research established that these leaders displayed behaviours that were change orientated, and a third category of leadership behaviour was established (Arvonen & Ekvall, 1991).
- Studies that evaluated the interaction between leadership behaviours in relation to a defined leadership goal acknowledge that a leader is likely to have simultaneous goals e.g., completion of tasks and employee retention. The behaviours used to complete these goals in isolation have been observably different. Task completion has been linked to clarifying and monitoring behaviours, and employee retention has been linked to relational behaviours (Yukl, et al., 2019). However, when a leader has simultaneous goals, the literature has not reached a clear conclusion on whether the simultaneous use of these behaviours is an additive process or a multiplicative process (Misumi & Peterson, 1985). Using descriptive data, there is a suggestion that behaviours are used in a pattern that the leader enacts for effectiveness, despite specific behaviours sometimes being contradictory (Kaplan, 1988) (Amabile, et al., 2004)

- Research studies completed to date have concluded that there is no identified universal set of leadership behaviours that will be equally effective in all situations (Fieldler, 1964) (Van Iddekinge, et al., 2009). This acknowledgement has led to the abundance of 'contingency' models within the body of knowledge (Larsson & Vinberg, 2010).

The studies completed to date have predominantly investigated the dyadic process between a leader and follower. There is an acknowledged gap of research that addresses the relationship between leadership behaviour and organisational activities (Yukl, 2009). In addition to this, the studies completed to date have had varying levels of abstraction present in behavioural definitions. As a result, there has been considerable overlap of identified behaviours with traits, skills, values and styles between research studies.

This wide variability of research construction has led to a fragmented field that has proven difficult to reconcile; Hunter et al identified 'at least 65 differing classification systems for leader behaviors' (Hunter, et al., 2011, p. 240). Many researchers have put forth criticism of the publication of theories and models that are not integrated with previously established knowledge, and have proposed frameworks for resolution of disparate works and identified areas for future research (Avolio, et al., 2003) (Pearce, et al., 2003) (Derue, 2011) (Batistič, et al., 2017).

Leadership Behaviour Taxonomies

One framework that has been proposed to address these criticisms is the establishment of behavioural taxonomies. There are several challenges in creating leadership behaviour taxonomies. The first challenge relates to the level of abstraction that exists in the conceptualisation of behaviours. Varying criteria and unstable definitions have led to difficulties in defining behaviours that are universally relevant. Yukl (1981) attributes this to the fact that behaviours, and behaviour categories, are interpretations of actions rather than independent, objective measures. As a result, a universally true set of behaviours cannot be created (Yukl, 1981). Therefore, taxonomical integration of leadership behaviour theory and models is impeded due to lack of consistent definition of behaviours and levels of abstraction. Compounding this challenge is the impact of the research methodology used to underpin behaviours selected for inclusion in a taxonomy. The use of factor analysis, judgemental classification and theoretical deduction suggests that the behaviours selected for a taxonomy will have different methodological bias. This results in mixed behaviour definitions and criteria overlap so that 'some taxonomies have fewer categories containing broad behaviour constructs, whilst others have more categories with more narrowly defined behaviour constructs' (Yukl, 1981, p. 64).

Despite this challenge, taxonomies of leadership behaviour have been created (Fleishman, et al., 1991) (Avolio, et al., 2003). However, the taxonomies have been developed to serve different communities e.g., identifying areas of future research opposed to planning leadership development, with different focuses. Two of the most notable behaviour hierarchal taxonomies are Fleishman's 1991 taxonomy and Yukl's hierarchical behavioural taxonomy. Fleishman's taxonomy has a problem-solving focus, whilst Yukl's taxonomy has a focus on behaviours most meaningful to subordinates, rather than leader performance (Hunter, et al., 2011).

Although Fleishman's taxonomy has been widely cited in the literature, this review will use Yukl's behavioural taxonomy for several reasons. Firstly, the taxonomy has been compiled more recently than Fleishman's, allowing more contemporary research to be included. Secondly, the taxonomy underwent factor analysis that supported the taxonomy structure. Finally, a meta-analysis of the taxonomy concluded by recommending that Yukl's taxonomy is used to underpin the future of leadership behaviour research (Borgmann, et al., 2016).

The taxonomy is comprised of four metacategories of leadership behaviours. Each metacategory is associated with a primary objective of a leader. The metacategories and objectives are shown in the tables below.

Metacategory	**Task**	**Relations**	**Change**	**External**
Specific Leadership Behaviour	Clarifying	Developing	Envisioning Change	Networking
	Monitoring	Supporting	Advocating Change	External Monitoring
	Short term planning	Recognizing	Encouraging Innovation	Representing
	Problem Solving	Empowering	Facilitating Collective Learning	

Table 1 Hierarchal Taxonomy of Leadership behaviour, adapted from **(Yukl, 2012)**

Metacategory	**Primary objective**
Task-oriented behaviour	the primary objective is to accomplish work in an efficient and reliable way.
Relations-oriented behaviour	the primary objective is to increase the quality of human resources and relations, which is sometimes called "human capital."
Change-oriented behaviour	the primary objectives are to increase innovation, collective learning, and adaptation to the external environment
External leadership behaviour	the primary objectives are to acquire necessary information and resources, and to promote and defend the interests of the team or organization

Table 2 Primary Objective of metacategory, adapted from Yukl 2012

In comparison to Fleischman's taxonomy, there is an omission of a behavioural component relating to 'organizing and evaluating information' (Fleishman, et al., 1991); Yukl (2012) states that the primary objective of externally focused leadership behaviour is to acquire information and resources but does not specifically name any behaviour relating to the critical evaluation of information. Yukl does not acknowledge this omission, although it may be connected to the focus of the taxonomy on subordinate meaningful behaviours.

The 2012 taxonomy is the first taxonomy that has named external leadership behaviour as a metacategory; Yukl's previous version contained only relation, task and change based metacategories (Yukl, et al., 2002). Yukl recognises that the use of factor analysis on questionnaires that are derived from existing behaviour metacategories does not examine the full range of leadership behaviour. The questionnaires were completed by subordinates who did not observe the leader in external situations, and therefore did not have the spectrum of experience to identify the external behaviours. Subsequently, the taxonomy also used the consolidation of descriptive methodology completed by several researchers, citing Ancona & Caldwell (1992), Joshi, Pandey, & Han (2009), and Marrone (2010), which identified 'boundary-spanning' behaviours as being important for effectiveness (Ancona & Caldwell, 1992) (Joshi, et al., 2009) (Marrone, 2010). Yukl concludes that 'the importance and uniqueness of external leadership behaviour provides justification for classifying it as a separate meta-category' (Yukl, 2012, p. 68).

The taxonomy is supported by other leadership behaviour researchers, who completed a meta-analysis to evaluate the importance of the specific leadership behaviours against the criteria of effective management and subordinate job satisfaction (Borgmann, et al., 2016). This meta-analysis followed the future research areas suggested by Yukl, who identified that some of the specific behaviours may be suitable for more than one metacategory (Yukl, 2012). Although the meta-analysis provided support for the taxonomy and Borgmann et al recommended that it was adopted for future research, Yukl et al published a refutation of one of Borgmann's key findings. The 2016 paper had concluded that change orientated behaviour was the most important for subordinate job satisfaction; this was challenged by Yukl, who completed a meta-analysis of leadership behaviour importance and concluded that relational leadership behaviour was the most relevant behaviour to subordinate job satisfaction (Yukl, et al., 2019).

A noted limitation of this taxonomy is that it cannot be said to be universally relevant, as it was evaluated without controlling for situational variables. As the situation is known to impact the effectiveness of leadership behaviour, discussed further in the next section, this is an area of future research that would be valuable.

Leadership Behaviours, Strategic Environments, and Innovation

The response to the constraints that an organization operates within can be called a strategy; 'A major responsibility for leaders at the executive level is to formulate an adaptation strategy that is relevant for the external environment and consistent with the organisations core competencies and ideology' (Yukl, 2009, p. 447). Smith (1997) builds on the multi-faceted nature of this responsibility, stating the 'strategy is associated with the long-term direction of the organization, the capacity of

the organization's activities, matching of those activities to its environment and resources, optimum allocation of major resources within the organization and, lastly, consideration of the expectations and values of the organization's stakeholders' (Smith, 1997). Jarzabkowski and Wolf (2010) posit that strategy is not a static artefact of the organisation, but is a series of actions that actors, including leaders, within the organisational system undertake (Jarzabkowski & Wolf, 2010).

The literature suggests that the connection of strategy to organisation performance is the responsibility of leaders, via the integrative system known as the business model. Neave (1990) acknowledges the integrative, systemic nature of a business model: 'The people work in a system. The job of the manager is to work on the system to improve it with their help' (Neave, 1990).

Business models may be traced to specialists in computing and systems modelling. They used the term to refer to computer simulations of business processes. It was argued that as the business environment became more complex, the potential value of business models would inevitably increase, and that as managers gain more knowledge in modelling techniques, computerized models should become an indispensable aid in many business functions. The original terminology of business model therefore referred to the ability to plan, control and predict innovation. However, business model (and modelling) morphed into a new meaning, referring to the creation of value in digital business (Drucker, 2001). The emergence of new technologies has led to an abundance of new terminology that incorporate the word 'digital' as a root metaphor (Avital, et al., 2019). When contrasted with industrial production, and the rationalised leadership practices that supported it, the use of digital as a root metaphor gives credence to the idea that different supporting leadership practices will emerge. Drucker stated that as early as 1950, there were predictions that the 'computer would in short order, revolutionise the work of top management' (Drucker, 2001, p. 98). Whittington (2019) supports this view by tracking the evolution of strategic planning over the previous sixty years, highlighting the increasing role that technology plays and the increasing focus on wider inclusion of stakeholders (Whittington, 2019).

As seen in the emergence of change orientated leadership behaviour, the ability to innovate successfully has become a requirement for a successful organisation (Arvonen & Ekvall, 1991) (Bass, 1996). The literature on innovation has developed in scope significantly from its origins in economic theory: a review completed by Martínez and López (2018) shows that the concept of innovation has been developed to include leadership practices, invention of new products and processes, competitive responses and organizational strategy (Martínez & López, 2018).

There have been several studies that aimed to investigate how leadership practices contributed to successful innovation. A significant portion of the studies identified the importance of leaders gathering information and using that knowledge to make decisions on innovation in the organisation. In these studies, there was variation in how this leadership activity was conceptualised. Rogan and Mors (2014) identified a specific leadership behaviour that supported innovation. The behaviour was the networking of leaders to gain knowledge and information to balance the decision between exploring new businesses and exploiting existing businesses (Rogan & Mors, 2014). This conclusion was supported by a study conducted by García-

Morales et al. (2018). This study used a higher abstraction level, by using a leadership style to investigate impact on organisation performance (García-Morales, et al., 2008). The relationship between transformational leadership and organizational performance was investigated. In this study, organisational performance was defined as the generation and revelation of knowledge, the ability to absorb knowledge, tacit knowledge, organizational learning and innovation. This is supported by a review of the latest literature that suggested that a strategy that focused on the generation of knowledge and subsequent insight is likely to be the most successful (Martínez & López, 2018).

García-Morales et al found that transformational leadership positively improved the organisation's performance. These findings were also later corroborated by empirical evidence (García-Morales, et al., 2012). This suite of research highlights that leaders can contribute to innovation by ensuring that the information and supporting networks that inform strategic decision making are as accurate and efficient as possible, as well as generating new knowledge within the organisation.

Vlok et al (2019) conducted a study that intended to identify leadership competencies that contributed to successful technological innovation (Vlok, et al., 2019). However, the researchers defined competencies as 'sets of behaviours that are instrumental in the delivery of desired results' (Vlok, et al., 2019, p. 256) and then did not identify any specific leadership behaviours, focusing instead on theories and leadership styles. Further abstraction was introduced by the discussion that competencies also include traits, knowledge, attitude, and expertise. The study claimed that it contributes 'newly identified leadership behaviours… technology connectedness, stakeholder alignment, liberating mind sets, value creation, and value realisation.' The study also identified that the deployment of the 'behaviours' did not need to be linear, and instead effective leaders deployed behaviours in response to the situation as required.

This level of definition of behaviours poses some challenges to integrate with existing leadership behavioural taxonomies, as it appears that some of the statements may be traits and skills rather than behaviours. This author would recommend that the statements are further investigated to establish if existing behavioural taxonomies anchor these areas e.g., stakeholder alignment could be as a result of using relational behaviours, rather than a behaviour. Despite the lack of clarity in the behavioural definition, the importance of stakeholder alignment is supported in other research; stakeholder collaboration and alignment were identified by Tuertscher et al. as a key factor in the development and deployment of complex innovative technological systems (Tuertscher, et al., 2014).

Vlok et al also claimed that the study recognises the importance of the role that the leader plays in integrating interdisciplinary teams throughout the innovation process. The successful integration of interdisciplinary teams as a factor contributing to innovation is supported in the wider literature; 'open collaboration' has been identified as a supporting factor in successful innovation (Martínez & López, 2018).

It appears that there is consensus within the literature that innovation, leadership, and technology are interrelated; however, the nature of the dynamics have not been empirically proven. There are some emerging perspectives on how leaders can contribute to the innovation process. The most identified leadership actions are

Information Network Management. Researchers have discussed aspects of this, such as the importance of external networking, the importance of multi-disciplinary teams and the generation and distribution of knowledge in the organisation (García-Morales, et al., 2012) (Martínez & López, 2018) (Tuertscher, et al., 2014) (Mortona, et al., 2020). In addition to these responsibilities, determining the most relevant data that should be collected and processed and acting in response to the insight generated has also been identified as a leadership behaviour in generating strategies that support innovation. (Tuertscher, et al., 2014).

Open Collaboration. This topic could be viewed as a subsidiary of information network management, due to the role of knowledge sharing. However, this author believes that it merits a separate discussion. This is due to the leadership behaviour that underpins open collaboration is likely to be different from information network management, although two areas would theoretically be mutually facilitative (Tuertscher, et al., 2014) (Vlok, et al., 2019)

There is significant divergency in the conceptualisation of innovation leadership. This is mirrored in the literature on leadership in a broader context; however, the recent efforts to rationalise the leadership research completed to date do not appear to have been integrated with the innovation focused literature, or vice versa.

Despite the high number of papers published regarding innovation, technology and leadership, there is no clear definitive path for practitioners to follow. It is also not clear whether the identified leadership practices that support innovation are supported in the leadership behavioural taxonomies, and therefore future research direction for the impact of innovation on leadership behaviours remains unclear. This challenge is becomingly increasing relevant due the impact of the 'fourth industrial revolution', discussed separately. However, innovation leadership actions appear to be aligned with some of the literature contained within the body of knowledge on knowledge management. The next section of the literature review summarises the findings from a search for relevant papers within this field.

Leadership Behaviour and Knowledge Management

Knowledge management literature was searched for studies that connected leadership behaviour with knowledge sharing and information network management. The concept of knowledge management concerns the design of organisations to maximise the value from the combination of technological resources and the human evaluation and response (Raisinghani, 2000). A leading theorist in this area is Peter Senge, who proposed the concept of a 'learning organisation' (Senge, 2010). He defined a learning organisation as 'organizations where people continually expand their capacity to create the results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning how to learn together' (Senge, 2010, p. 14). Senge identified 'pillars' of learning organisations:

- Personal mastery as a discipline of continually clarifying and deepening our personal vision, of focusing our energies, of developing patience, and of seeing reality objectively.
- Mental models are deeply ingrained assumptions, generalizations, or even pictures of images that influence how we understand the world and how we act.
- Building shared vision - a practice of unearthing shared pictures of the future that foster genuine commitment and enrolment rather than compliance.
- Team learning starts with 'dialogue', the capacity of members of a team to suspend assumptions and enter into genuine 'thinking together.
- Systems thinking - The Fifth Discipline that integrates the other four

Within these five pillars, correlation with the behaviours identified by Yukl in the behavioural taxonomy can be seen. Senge calls out clarification, relational connections and building a shared vision, as does Yukl.

The literature within knowledge management has predominantly focused on the implicit knowledge codified in the culture and structures of the organisation; however, focus is beginning to turn to bringing in external knowledge to create value for the organisation (Gold, et al., 2001) (Robinson & Simmons, 2021) (Martini, et al., 2017). This aligns with the behaviour of external monitoring most recently added to the taxonomy of leadership behaviour, as well as the direction of the innovation strategy literature on open collaboration. Other research has focused on servant and transformational leadership styles and knowledge management, finding that knowledge management had a moderate effect on employee development when used in combination with servant and transformational leadership styles (Alnajdawi, et al., 2019). The servant and transformational leadership styles are most closely connected with the relations and change orientated metacategories in the hierarchal behavioural taxonomy.

The next section of the literature reviews the body of knowledge on Industry 4.0 for key hallmarks of the concept that may impact the response of leaders.

Industry 4.0

Industry 4.0 is an ‘umbrella’ term that refers to the current era of emerging, adjacent technologies. It was coined as ‘Industrie 4.0’ by the German government at Hannover fair in 2013 as part of the country’s industrial strategy. The concept is being viewed as the ‘Fourth Industrial Revolution’, with the changes brought about forecast to add 3.7 trillion USD to the global economy by 2025 (Mckinsey & WEF, 2018). It is recognised that the changes required will be profound, involving shifts in the power source at a societal level and requiring perspective changes from all stakeholders. Mrugalska and Wyrwicka (2018) state that ‘’The next industrial revolution based on the Internet of things and new technologies is not a continuation of current trends in automation. It results from the changes of the philosophy of creating systems responsible for the product or service’’ (Wyrwicka & Mrugalska, 2018, p. 1). The fourth industrial revolution is expected to improve productivity, allowing more wealth generation per unit of investment (Schwab, 2017). Characteristics of the fourth industrial revolution are

1. ‘’radical changes linked with the advent of new technologies, [which] makes the diffusion of innovation much faster than at any time in the past.’’ (Kohnová, 2018, p. 65)
2. unprecedented scope of change (Schwab, 2017)
3. systemic impact as a result of exponential change happening in all areas (Schwab, 2017)

The academic response to Industry 4.0 has also been strong: Dohale and Kumar conducted a literature review in 2018 that aimed to establish an overview of Industry 4.0 literature (Dohale & Kumar, 2018). The review showed that the quantity of published papers that referred to Industry 4.0 increased significantly over the three years preceding the review. The analysis also showed that many of the papers were conceptual in nature, and that the available literature was lacking a commonly accepted definition of Industry 4.0. It was also noted that the definition of Industry 4.0 was divergent between academia and industry. The observation that a lack of definition exists was also found in research conducted by Vogel-Heuser and Hess, and Kohnová (Vogel-Heuser & Hess, 2016) (Kohnová, 2018). Mioriandi et al highlighted that this lack of definition affects the coherence of the available literature, specifically that the ability to analyse the interactions between technologies is limited (Miorandi, et al., 2012). Halse & Jæger found that studies have predominantly focused on the maturity and readiness for adoption of individual technologies. (Halse & Jæger, 2019).

Definitions of Industry 4.0 have been proposed, with shared themes such as discussing systemic change, technology and interfaces with humans. The definitions have created terminology such as ‘cyber-physical systems’ (CPS) to emphasise the connection between physical devices and software systems (Kohnová, 2018). One of the barriers to establishing a definition is the emergent nature of the technologies, as definitions that are too closely linked to the application of the technology have the risk of being outdated as the technology evolves. However, the lack of commonly accepted definitions of Industry 4.0 and the technologies that it covers is highlighted as a factor that is impeding the pace of adoption and knowledge in industry and academia. Therefore, a suitably scoped definition is required. Pfohl et al proposed that "Industry 4.0 is the sum of all disruptive innovations derived and implemented in a value chain to address trends in digitalization, autonomy, transparency, mobility, modularization, networking and socialization of products and processes." (Pfohl, et al., 2015). This definition has a suitably broad scope that minimises the risk of irrelevancy and has been adopted by other researchers (Kohnová, 2018). Therefore, to avoid further fragmentation, this is the definition that will be used throughout this literature review.

Architecture of Industry 4.0

As highlighted, one of the characteristics of Industry 4.0 is technological change. This shifting and evolving nature presents a challenge to research to identify an appropriate lens for the research study. There is variation in the literature of how researchers have identified core technologies for Industry 4.0, with some including application-based interpretation, cloud based manufacturing and smart manufacturing (Schumacher, et al., 2016). An industry-based view from Price Waterhouse Cooper, in conjunction with the World Economic Forum, focused on ‘rapid advances in artificial intelligence, the Internet of Things (IoT), robots, autonomous vehicles, biotechnology, nanotechnology and quantum computing, among others. It is characterised by the combination of

these technologies, which are increasing speed, intelligence and efficiency gains' (Herweijer & Waughray, 2018).

Due to the fickleness of application that is to be expected in Industry 4.0, this researcher proposes that a three-tier perspective of technology is used, based on the main functionality. By using this framework, technologies can be categorised and evaluated alongside similar concepts. A review of the available literature on specific technologies has highlighted the following technologies as being included in the scope of Industry 4.0. This section aims to give the reader an overview of the structure of Industry 4.0, with specific application, enablers and challenges explored in the following chapter.

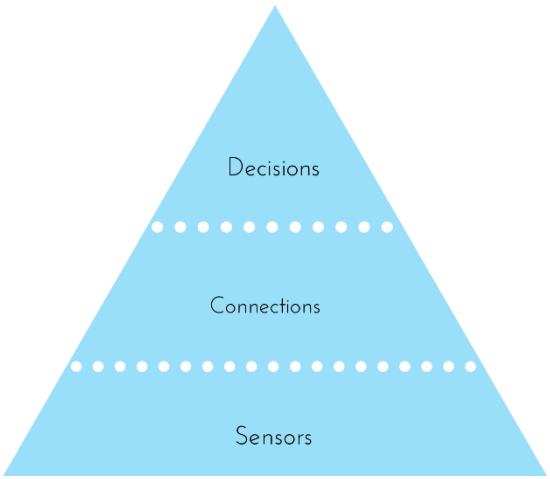

Figure 3 Proposed Industry 4.0 Tiered Technology Framework

Tier One: Sensors

The collection of data is a foundation of Industry 4.0. Examples seen in the literature predominantly use sensors such a Remote Frequency Identified Devices (RFIDs) to collect data on location of devices (Caputo, et al., 2016) (Giudice, 2016). Other sensors are used to measures characteristics such as temperature, humidity and pressure (Scuotto, et al., 2016).

Tier Two: Connections

Internet of Things

The Internet of Things (IoT) is also known as the Industrial Internet, or sometime Industrial Internet of Things (IIoT). The Industrial Internet of Things 'includes smart agriculture, smart cities, smart factories and the smart grid.' (Rong, et al., 2016).

It is a concept that refers to the system that will allow a flow of data to and from tier one sensors. One of the most common definitions used was proposed by the International Telecommunication Union (ITU), which defined the Internet of Things as "a global infrastructure for the Information Society, enabling advanced services by interconnecting (physical and virtual) things based on, existing and evolving, interoperable information and communication technologies" ((ITU 2012, cited

by (Wortmann & Flüchter, 2015)). However, there are multiple definitions proposed in the literature, recognised by Wortmann and Flüchter, and Atzori. Atzori proposed that the 'fuzziness' around the internet of things was based in the syntax of the name 'Internet of Things', and posited that the intent of the stakeholder would push towards a network-based definition or a 'things'-based definition. To reconcile research, Atzori categorised the available definitions into three paradigmatic statements (Atzori, et al., 2010). To provide further coherence, this review also aligns the paradigmatic statement with the four characteristics of the Internet of Things proposed by Caputo et al (Caputo, et al., 2016).

1. a 'Things oriented" paradigm that views the IoT as a network of identifiable objects. This is supported by the first characteristic of the Internet of Things identified by Caputo et al 'The IoT is populated by unique identified items''.
2. an 'Internet oriented' perspective that is summarized as a "world where physical objects are seamlessly integrated into the information network, and where the physical objects can become active participates in business processes.'' This is supported by the second characteristic identified by Caputo et al 'The IoT is populated by active items''
3. A 'semantic oriented" view which focuses on the data generated by the Internet of Things and assumes that interfaces other technology will be required to derive value. This is supported by the third and fourth characteristics identified by Caputo et al 'The IoT is an environment populated by items that produce a flow of data'' and ''The IoT is an environment populated by items that constantly exchange data with each other''

This paradigmatic view of the Internet of Things is also aligned with the perspective proposed by Giudice, who states that the Internet of Things is comprised of 'three layers of three kinds of things: the physical, the digital and the virtual entities' (Giudice, 2016).

Blockchains

Blockchain technology is also known as distributed-ledger-technology (DLT). This technology is characterised by recording transactions in a decentralised network. Vijai et al state that 'the technology works as an electronic transaction-processing and record-keeping system. This allows various participants that are connected to the network, usually public, to track information through a secure network, thereby eliminating the need for any kind of third-party verification' (Vijai, et al., 2018). Zheng and Dia go further, highlighting the value of the technology '' As committed transactions in the blockchain have been stored at every node, they are extremely difficulty [sic] to be altered or falsified. Integrating with digital signature and asymmetric encryption, blockchain data is authenticated and auditable, implying non-repudiation of the transaction initiator. The length of blockchain keeps growing with the new validated transaction being appended at end of the chain. Data analytics on blockchain data can potentially extract valuable information.'' (Zheng & Dai, 2019)

Tier Three: Decisions

The third-tier concerns technology that responds to the data passed from tier one through tier two.

Artificial Intelligence

The paradigmatic view of the tier two technologies allows for analysis of adjacent tier three technologies. In the case of artificial intelligence (AI), the second paradigm of the internet of things is most relevant. The second paradigm deals with devices that are active participants in a network. This 'active' part of the paradigm is the adjacency point to artificial intelligence.

The field of artificial intelligence aims to establish mechanisms that allow active devices, known as 'agents' to interact with the environment and between themselves in pursuit of a 'global given goal' (Miorandi, et al., 2012). One of the noted challenges in achieving this is how to manage the agents to select an appropriate strategy to allow the resolution of a problem or to identify and achieve a goal. (Kannengiesser & Müller, 2013).

Artificial intelligence has also recently been recognised as an adjacent technology with blockchains; Zheng and Dai call this 'Blockchain Intelligence' (Zheng & Dai, 2019). The role that artificial intelligence takes is maintaining the operational capability of the blockchain and detecting defined malicious behaviour.

Big Data

The third paradigm of the connective tier two is that it is a source of data. The requirement to manage the high volume of data has led to several techniques being developed, such as 'machine learning, data mining, crowd sourcing and time frequency analysis… Techniques such as these have become known as 'Big Data'' (Berawi, 2018)

Berawi proposes that the advancements made in these techniques have been driven by the acknowledgement that 'data has become valuable knowledge that can be organized, managed, and utilized to enhance productivity performance and further innovation in order to gain more competitive advantages for organizations' (Berawi, 2018)

Industry 4.0 and Leadership Behaviour

A review of the literature was completed that aimed to identify the enablers and challenges that leaders face in Industry 4.0. The literature is as fragmented as the definition and conceptualisation, however there are areas of strong agreement.

Industry 4.0 does not have a shared definition and Miorandi has identified that the contextualisation of the Industry 4.0 concept varies (Miorandi, et al., 2012). Halse and Jæger conducted a study with small to medium manufacturing enterprises to investigate the role of Industry 4.0 technologies in creating a circular economy business model. They identified a duality in the conceptualisation of Industry 4.0. The duality is that the Industry 4.0 'represents both innovation (exploration) and efficiency (exploitation)' (Halse & Jæger, 2019, p. 136). The researchers posited that this ambiguity may create tension in identifying how to respond to the concept, and further stated that it is the responsibility of the company's management to resolve any tension. As an example of how the tension might manifest, they stated that 'new business models involve radical and sometimes disruptive innovation, which is associated with exploration, while increasing efficiency of

manufacturing reflects exploitation of existing assets' (Halse & Jæger, 2019, p. 6). Giustiniano also recognises the same dynamic, stating that 'leaders should: – (exploit) the existing and necessary business with its hierarchical and complex projects' structures, to allow a basic efficiency … and – (explore) innovative, flexible and agile processes and business models, to address new opportunities.' (Giustiniano, 2018, p. 258). This ambidextrous approach to innovative strategy is supported in the organisational strategy literature (Rogan & Mors, 2014) (Martínez & López, 2018). However, this duality is not acknowledged consistently across the Industry 4.0 literature. Sanhavi et al reason that Industry 4.0 is not a revolution as it is a normal progression and improvement on current technology (Sanghavi, et al., 2019).

Acknowledging the duality of the conceptualisation allows the literature review on enablers and challenges to be structured further, as the aim of the organisation of either exploration or exploitation offers a position from which to explore the impact of specific factors.

Exploitation

Companies that choose to recognise the exploitative response to Industry 4.0 focus on how to increase value within existing value streams and processes. The source of the value comes from an increase in productivity, increasing the ratio of value created to effort invested (Schwab, 2017). Identifying the particulars of how Industry 4.0 will do this has led to researchers proposing several different options

Sanghavi et al state that 'accurate results are being produced and accurate losses are being identified which in turn helps increasing the productivity' (Sanghavi, et al., 2019, p. 9). Halse and Jæger reported that the significant number of participants also 'emphasized the possibility to improve the efficiency of manufacturing processes' (Halse & Jæger, 2019, p. 5). The justification for accuracy of data as a source of productivity improvements is limited, as data by itself does not create change in process or procedure. Sanghavi et al do not offer any further insight into how accuracy could be foundational in productivity improvements, although they do implicitly recognise the importance of data usage by recommending the use of a metric to measure the 'data efficiency' of an organisation. The metric is formed by monitoring all the data available to an organisation, the quality of the data and aggregated and used data. The difference between data available and data used could be a leading indicator of 'poor algorithm, poor data integration and poor management' (Sanghavi, et al., 2019, p. 10).

Giustiniano identifies that work such as 'administrative coordination and control (e.g., shifts of personnel; report writing)' could be completed by artificial intelligence systems (Giustiniano, 2018, p. 258). This would increase productivity by creating more efficiency in the completion of these tasks, and lessening the workload completed by humans. However, the effort required to train an artificial intelligence system to create meaningful report is recognised as a barrier. Giustiniano explores this challenge further and identifies that 'deep learning-based AI systems can figure out the important features for solving difficult problems that were once thought to be solvable exclusively by humans' (Giustiniano, 2018). By making this observation, Giustiniano highlights a strategic challenge is matching the right technology to the right task at the right time. The right time is a

particular challenge due to the recognised exponential and emergent nature of Industry 4.0 (Schwab, 2017).

Within the wider strategy of exploitation, there is a consensus in the literature that there will be an impact on the incumbent workforce. There are two areas of impact that have been primarily discussed in the literature, the impact on skills and therefore role retention, and the impact on the wider organisational structure and working patterns.

Skills and role retention is likely to be impacted due to the development of cyber-physical systems (CPS) that contain Industry 4.0 technologies (Ninan, et al., 2019). Cyber-physical systems refer to the integration of humans and technology into processes (Kohnová, 2018). Halse and Jæger postulate that the content of the work completed will change as a result of this restructuring of tasks within this network (Halse & Jæger, 2019). Sanghavi et al support this, stating that 'a restructuring of labour division within the manufacturing division will also take place; Factory workers must be skilled in making decisions.' (Sanghavi, et al., 2019, p. 10). Decision making is also highlighted as a central skill by Godina and Matias, and Giustiniano who proposed that the 'workforce management models adapt to smart machines and hyper-connected teams allow firms to become much faster and agile in making decisions', however Giustiniano identified that leaders become integrated in the cyber-physical system 'leaders and machines to become "colleagues", by working and making decisions together' (Giustiniano, 2018) (Godina & Matias, 2019). Barriers in achieving this have been identified as 'worker compatibility with the new technology' (Sanghavi, et al., 2019, p. 9)

The impact of this change in task structure is forecast to be increased flexibility in working patterns and organisational structure. The literature has consensus that the most effective organisational structures will be flatter hierarchies and networked organisations that are multidisciplinary (Giustiniano, 2018).

Exploration

The identification of opportunities to create value by exploring new applications of Industry 4.0 is seen as a higher risk approach by some practitioners. The study by Halse and Jæger showed that the development of new business models was the first aim of Industry 4.0 adoption for most enterprises, however a study by Deloitte showed that there are varying levels of confidence shown by leaders to be able to successfully change the business model (Deloitte, 2015). A barrier to identifying opportunities for value is the lack of appropriate method. One of the most used calculations in contemporary business practice is Net Present Value (NPV), which was evaluated by Lee and Lee for use with Industry 4.0 technology. The evaluation found that due to the lack of inclusion of reversibility and scalability in the assessment of value, it was not a suitable method of assessment (Lee & Lee, 2015). No other method of assessing value was proposed. In addition, Bryson proposed that the definition of assets will be impacted by Industry 4.0 technologies 'In the knowledge age, the most important business assets are not the tangible assets of the past. Intangible assets such as knowledge, expertise, innovation and branding are the new business enablers.' (Bryson, 2006, p. 3)

In the exploration scenario, integration of systems and organisational functions becomes more likely. Researchers have identified that there are several skills that enhance effective integrations, such as collaboration, creativity and knowledge management (Donate & de Pablo, 2015) (Zakaria, et al., 2019). In integrative structures, Giustiniano recommends against ''any "race against the machine" approach by trusting the advice of intelligent systems in making everyday business decisions'', which could be classed as a knowledge management competency (Giustiniano, 2018). In a highly networked, integrative organisation, skills that promote positive teamwork that cannot be replicated by machines are highlighted as important. Examples in the literature are 'empathy, ethical reflection, creative thinking and capacity to improvise, creative thinking and curiosity; social skills, networking and coaching to bring together diverse perspective, insights and experiences.' (Giustiniano, 2018, p. 258). Sanghavi et al reference these skills at a higher level of abstraction, stating that 'coordination between the social and environmental dimensions is quite necessary' (Sanghavi, et al., 2019, p. 12).

In an organisation pursuing the value available by using Industry 4.0 in the exploitation of existing processes and products, there may be an impact on the organisational structure to make it flatter and more networked. For those companies who are pursuing exploratory value, there are further opportunities in integrative structures. Zakaria et al identified integration as an Industry 4.0 opportunity, stating that 'the integration of knowledge is core necessity of industry 4.0 which leads a company towards success' (Zakaria, et al., 2019). Miorandi et al identified that vertical and horizontal integration of systems offers value in efficiency, which Deloitte also supported (Miorandi, et al., 2012) (Deloitte, 2015). Sanghavi et al further identify end to end integration as an available structure (Sanghavi, et al., 2019).

In order to integrate systems, organisations must overcome significant logistical and technical challenges, identified by Pietrewicz, 'combined integration of ICT systems across manufacturing stages and hierarchical levels along entire value chains creates an unprecedented coordination challenge' (Pietrewicz, 2019). Sanghavi et al supports this and identifies the main requirements for success as 'the correct definition of mechanical, electrical and communication standards for each specific subsystem of the supplier. This standardization is essential to ensure interoperability between all the different modules of the production line' (Sanghavi, et al., 2019, p. 8).

The literature has identified two modalities of exploitation and exploration in the conceptualisation of Industry 4.0, and associated opportunities and challenges in the areas of value identification, skills and organisational structure. However, there are additional opportunities and challenges that are not necessarily directly linked to either modality.

Researchers are anticipating that technical and pragmatic challenges such as modifying current tools and machines, data management integrity, including protection against data loss and corruption and standardisation of Industry 4.0 platforms, process and technologies will play an active role in the pace of adoption (Godina & Matias, 2019) (Halse & Jæger, 2019) (Sanghavi, et al., 2019). Organisational specific challenges were also identified, such as capital investment and intensity. Halse and Jæger found that the investment required in Industry 4.0 technologies was the biggest

barrier in implementation. It is noted that this study was conducted on small to medium enterprises, and so cannot be univerally generalised to all organisations. However, two of the contributing factors to challenges accessing investment was the risk associated with being an early adopter, and lack of empowerment in subsidiary areas to access capital.

A review of how accepted management tools correlated with readiness to introduce Industry 4.0 technologies into manufacturing found that 'the use of six sigma, total quality management, radio frequency identification, a balanced scorecard, rapid prototyping, customer segmentation, mission and vision statements, and digital transformation is positively associated with Industry 4.0 readiness' (Crešnar, et al., 2020, p. 2). Barriers such as 'outsourcing and strategic planning' are viewed as barriers to Industry 4.0 readiness (Crešnar, et al., 2020).

Other research has found that competency and skills in the workforce is the biggest barrier to implementing Industry 4.0 technologies (Karadayi-Usta, 2018). The study determined that "lack of education system" is the root factor in Industry 4.0 barrier to implementation, and has connections to other barriers such "workers' resistance" against the transformation, "lack of perseverance" of the employees, difficulties in "finding qualified personnel," "lack of readiness for innovation," and "lack of ICT adoption''. This finding is supported by a separate study that found that employees with a higher level of education were more likely to engage with management tools that supported the introduction of Industry 4.0 (Nedelko, 2021).

The impact on the workforce of applying artificial intelligence is likely to replace the use of low-cost labour. The economic impact of this is likely to be geographically diverse; Sanghavi et al identifies that in low-cost economies such as India, automation takes away job opportunities. Additionally, areas of the world that do not have stable and secure access to electricity and internet connections are likely to be further disadvantaged as organisations with more stable infrastructure benefit from the increased productivity and wealth generation offered by Industry 4.0 technologies. These two factors could mean that overall global inequality could rise as a result of Industry 4.0. This risk of increased inequality provides a sense of urgency to the research conducted; as Nobel laureate in economics Professor R.J. Shiller states 'we cannot wait until there are massive dislocations in our society to prepare for the Fourth Industrial Revolution' (Shiller, 2016). The inequal access to the opportunities provided by Industry 4.0 could offer insight into why there is significant variation amongst global executives about Industry 4.0 opportunities; 8 percent executives of Asia- Pacific (APAC) have confidence to lead technological change, contrasting with 36 percent from the Europe, Middle East, and Africa (EMEA) region and 48 per cent in the USA (Deloitte, 2015). Additionally, the environmental impact of Industry 4.0 is not fully understood. The literature identifies that sustainability can be a factor that motivates organisations to utilise Industry 4.0 technology, however the consumption of raw materials and power sources by the production of sensors and networks has not been fully evaluated (Halse & Jæger, 2019) (Sanghavi, et al., 2019).

Conclusion

This chapter concludes by identifying the key literature that the researcher used to conceptualise the study and the specific gap in knowledge that the research study aims to address.

The literature shows that Industry 4.0 has the potential to disrupt the strategic environments that organisations operate in and it will require leaders to provide a responsive strategy to adapt to the impact of the new technologies. The literature on leadership has identified that leadership behaviours are an appropriate lens to evaluate the impact, due to their proximity to action (Derue, 2011). Yukl's hierarchal behavioural taxonomy has been identified as the most comprehensive, contemporary consolidation of available research on leadership behaviour (Yukl, 2012).

As Industry 4.0 unfolds, the literature shows the emergence of some considerations for leaders. Riggins states that 'from an organizational usage perspective important questions include how organizations use this technology to serve customers better, to change the role of employees, and how employee privacy may be threatened.' (Riggins & Wamba, 2015). Drucker proposes more concrete actions, in the form of questions executives should ask 'what information do I owe to the people with whom I work, and on whom I depend? In what form? And in what timeframe? / what information do I need myself? From whom? In what form? And in what time frame?' (Drucker, 2001, p. 124). He extrapolates these questions into indicative behavioural anchors 'Executives have to learn two things: to eliminate data that do not pertain to the information they need: and to organise the data, to analyse, to interpret – and then to focus the resulting information on action' (Drucker, 2001, p. 130). However, the exponential nature of Industry 4.0 is shown in that some researchers recognise that the management of data may not be a leaders' responsibility in the future 'IT-based tools such as algorithmic decision-making may become part of automated strategizing processes' (Mortona, et al., 2020, p. 15).

The ramifications of integrating Industry 4.0 technology into foundational business and value generating practices are not clearly understood. A wide range of industry and academic reports have identified that the technologies have the potential to increase productivity. However, there are significant challenges to overcome; this literature review has identified leadership challenges in developing employee skills, redefining business models, optimising the organisational structure and integrating IT systems. The literature suggests that open collaboration, ambidextrous strategies and the development of knowledge management-based leadership behaviours are enablers to help practitioners overcome these barriers. Literature shows that that practitioners are engaged with Industry 4.0 efforts to a high degree; 'the ambition to exploit Industry 4.0 technologies is high among top management; the barriers were considered less important than the motives' (Halse & Jæger, 2019, p. 140).

This study aims to contribute to closing the gap in the literature between leadership behaviours and Industry 4.0 enablers and challenges. The key theory that underpins the conceptualisation of this study is the hierarchal behavioural taxonomy developed by Yukl (Yukl, 2012). This literature was selected due to its role within the body of knowledge of serving as a point of consolidation of research on leadership behaviour; by using it to underpin the research study, the risk of introducing

fragmentation into leadership behaviour is reduced. This view is supported by other researchers; Borgmann et all recommend that the taxonomy is used to underpin further research (Borgmann, et al., 2016). The Industry 4.0 enablers and challenges have been conceptualised based on the research conducted by Giustinianio (2018), who provided one of the more recent overviews of Industry 4.0 and management challenges (Giustiniano, 2018). In addition to Giustiniano's work, definitions and conceptualisation of the technologies have been based on the research conducted by Miorandi et al (2012), Atzori et al (2010), and Caputo (2016) (Miorandi, et al., 2012) (Atzori, et al., 2010) (Caputo, 2016).

Chapter Three: Research Design and Methodology

Introduction

Defining the process of enquiry most suited to answering the research question is a core responsibility of the researcher. This activity is known as research design. Collis and Hussey (2003) state that credible research must demonstrate 'methodological rigour', which they further define as 'the application of systematic and methodical methods in conducting the study and a careful, exacting approach' (Collis & Hussey, 2003, p. 19).

A robust approach to research design is key for several reasons.

1. A well-defined research approach controls the scope of the investigation, allowing for efficient use of time and research funding
2. Clarity and transparency of the research design allows the investigation to be peer reviewed appropriately. It also allows fellow researchers to replicate the research study to evaluate the strength of the findings.
3. For many fields of study, the researcher may have conscious or unconscious bias that affects the investigations. By making the research design process explicit, the researcher has more opportunity to examine the motivations and preconceived ideas and adjust the research design accordingly.

When evaluating the research design to establish the most appropriate approach, several factors may be taken into consideration. Some of the most considered factors are the philosophical assumptions of the researcher, the skill level of the researcher and logistical limitations. The analysis and subsequent decisions in these areas must be justified by their impact on achieving the research objectives. In some cases, there may be multiple ways of achieving the same objective, and the researcher must identify the most appropriate.

This chapter provides a record of the analysis of research design options available, and the subsequent decisions and justifications for the choice of methodology used to fulfil the research aims and objectives. A reflection on the impact of the researcher's motivations, values and philosophical outlook is also provided. This chapter includes discussion of the methods of data collection, analysis, and management. A review of the pilot data collection and analysis is also included, which identifies the changes subsequently made to the research design. An evaluation of interview participants and their significance in the study is presented, as well as the actions taken to recruit, engage and retain the participant input. The ethical considerations and protections that have been put in place are also documented. The chapter concludes with an acknowledgement of the inherent limitations of the research design.

Research Question and Objectives

A review of the literature highlights that extensive research has been completed on leadership behaviour, which has identified that the strategic environment is one of the key factors that

contributes to impactful leadership behaviour (Vinber, 2010). The strategic environment is populated by a range of influences, which wax and wane in accordance with wide macro trends. The literature review of the strategic environment highlighted the role of technology as gaining in influence in the strategic environment. The impact of specific types of technology has led to discussions of a fourth industrial revolution, led by connected intelligent devices. For organisations, the strategic environment that they are now forecasting to operate in is known as Industry 4.0. A review of the literature available on Industry 4.0, and the adjacent technologies that it refers to, shows that the academic knowledge is in its infancy. It is acknowledged that the research to date is fragmented and focuses on the technological applications (Caputo, 2016).

The research study question is ''How do strategic leadership behaviours intersect with Industry 4.0?'', which reflects the aim to examine how strategic leadership behaviour responds to the opportunities and challenges of Industry 4.0 technologies. This study can therefore be broken down into objectives, each objective aiming to answer a component of the study. The objectives are

1. Evaluate to what extent previously identified leadership behaviours are present in strategic leader responses to Industry 4.0
2. Identify if any uncategorised behaviours are being exhibited in strategic leader responses to Industry 4.0
3. Evaluate the behaviour demonstrated by strategic leaders in response to Industry 4.0 in comparison to the enablers and inhibitors identified in the literature to date
4. Identify any additional enablers or inhibitors that are impacting strategic leader behaviours in the Industry 4.0 context

Research Design

'As a potentially unlimited number of research questions and ways to work on them exist, preferences for theories and methods as well as the researcher's interests, competences, skills, and sensibilities, acquired during (professional) socialization within specific academic contexts and 'schools,' play a crucial role within this initial process' (Mey, 2007, p. 519). As Mey states, the impact of the researcher on the study starts before the data collection and analysis is planned. What motivates an individual to identify and investigate a research problem, and how they choose to frame that question is a subjective process. The available choices of methodology to carry out an investigation have been aligned down qualitative and quantitative paradigms, with data interpreted through interpretivist or positivist lens.

''Qualitative research often involves the collection of people's experiences, views and opinions in their own words'' (Braun, et al., 2014, p. 184). As a result, qualitative data often supports an interpretivist perspective of data, with the researcher recognising that the participants are reporting on their view of reality. The subjective interpretation of qualitative data has been a highly discussed issue due to the potential of researcher bias influencing results. As a result, research studies that have involved qualitative analysis by researchers have been subject to critical scrutiny due to the increased likelihood of bias. Houghton and Houghton state that 'novice qualitative researchers should be aware of an unfortunate credibility gap' (Houghton & Houghton, 2018, p. 3522). However,

the background and experience that brings a researcher to the point of investigation is subject to bias, but it could also be framed as the researcher experience also gives the researcher the insight to recognise a research problem.

The perspective of the Researcher

The original identification of the current research problem came from the researcher's experience in industry and observations in their early career. The researcher was an employee of General Electric (GE) in 2012 and participated in a Higher Apprenticeship in Leadership and Management. The Higher Apprenticeship was also supported by in depth commitment by the organisation in the form of mentoring and exposure to high level executives. Throughout the period of the apprenticeship, GE corporate would often send internal emails referencing a transformation and repositioning of the company as a 'digital industrial' company, rather than their previous model of being purely industrial. As part of these communications, references to 'smart factories' and 'internet of things' were made.

Within the Higher Apprenticeship, the researcher was expected to be aware of, and able to analyse, the strategic environment in academic assignments. However, literature searches showed there was limited information available on what the implementation of the referenced technologies would look like. Within the organisation, through executive exposure opportunities such as roundtables and Q&A sessions with senior leaders, questions regarding the value and meaning to employees of the transformation efforts were only superficially answered. The discussions focused on the technology, rather than the organisation, and detailed alignment of the two was not available.

For the researcher, the timing of this change was powerful. The Higher Apprenticeship provided a context where a focus on acquiring skills for future careers was emphasized, and it became apparent to the researcher that there was not a clear answer to the question: ''Considering the forecast impact of new technology, what leadership skills and behaviours do I need to future-proof my career?' Additionally, the researcher was being trained in leadership and management of engineering and technology organisations, despite not having any engineering qualifications. The viewpoint of the learning and development executives was that it was often better to have leaders without technical skills leading engineering teams, to provide counterbalance. This counterbalance was expected to be demonstrated through behaviour, rather than technical skillset. The researcher was motivated to know whether this would hold true in the face of the forecast technological changes.

This observed gap led to the researcher to approach Robert Gordon University to see if it would be suitable to form the basis of a research project. A professional doctorate pathway was identified as suitable, due to the focus on the applications to practice and the researcher's commitments to full time employment.

This focus on practice has remained throughout the progression of the research project. The high level of influence by professional practice on shaping the researcher's question and objectives has led to the consideration of identifying the researcher as a practitioner-researcher. A research practitioner is conceptualised as a researcher whose studies take place in the organisation which

employs them (Saunders, et al., 2009). One advantage of this arrangement is that gaining access to research data is likely to be easier. Another advantage is that more in depth knowledge of the organisation is available, allowing more complex research problems to be addressed. However, this close familiarisation with the organisation has also been highlighted as a potential shortcoming that could affect the quality of the data collection. Saunders et al states that 'we found it very useful to ask ''basic'' questions revealing our ignorance about the industry and the organisation. These ''basic'' questions are ones that as the practitioner-researcher you would be less likely to ask because you, and your respondents, would feel that you should know the answer already'' (Saunders, et al., 2009, p. 151).

The dilemma introduced by being a practitioner-researcher is that there is some inherent conflict between observing the data whilst being aware of, and managing the expectations, of the study participants. This is further complicated if there is a power disparity between the practitioner-researcher and the research participants.

For these reasons, this study was not completed within the organisation that the researcher is employed by. However, the study was completed within the researcher's professional network, and so the factors discussed so far still apply to some extent. The access to research data was made easier by existing professional relationships, and the professional reputation of the researcher. By basing the study outside of the organisation, over-familiarity was avoided; however, selecting organisations in similarly structured industries allowed the researcher to have credibility when recruiting and building relationships with participants.

The structuring of the research study in this manner allowed many of the benefits of practitioner-research to be retained whilst minimising some of the more detrimental aspects. However, a documented challenge of maintaining professional practice and completing research studies is that combining the two modes of work can be challenging, particularly for time management. In this study, this was managed by using holiday allowance from the employing organisation to pursue data collection. The use of holiday allowance in the earlier part of the study allowed the researcher to create physical and mental capacity of the completion of the research. However, in the latter part of the research project, the Covid-19 work from home directive introduced the challenge of not being able to create a physical space separate from the demands of full-time employment. This had a surprisingly high negative impact on the progression of the research project.

Another potential risk that the practitioner-researcher courts is that of managing their reputation and their perception by their peers. Academia can sometimes be viewed as idealistic, overly theoretical or 'woolly' by practitioners, and so attempts to influence professional practices based on the research study must be managed to avoid negative associations. In these instances, it is imperative that the practitioner-researcher can convey the value of their research concisely and in language that is accessible by their practitioner peers. Tools available for developing this are the 'elevator speech' of the research study. This is further discussed in the managing participants sections of this chapter.

The Researcher's journey

The process of preparing for and completing the research study takes place over a considerable period. Influences on the research and practice can be subtle and not register at a conscious level, which poses the risk of having unacknowledged factors present.

The development of the researcher throughout the completion of study has been more encompassing than anticipated. The pragmatism that triggered the motivation and research inquiry progressed into a deeper and more meaningful appreciation of the role of leadership and the scale of the potential impact of Industry 4.0.

Research Impact on Practice

The impact of the researcher's motivation and lived experiences on the research has been discussed. In the context of researchers who are also practitioners, consideration of the impact of the research experience has on the practice can also be discussed. One of the main impacts on the personal practice of the researcher that has been noted is the increased strategic understanding of the importance of maintaining a healthy, ongoing innovation ecosystem for an organisation. Previously, practice focused on objective-based change efforts that promoted innovation, but as standalone, time bound projects. As a result of undertaking the research project, the researcher's practice is now more focused on smaller, consistent efforts that contribute to systemic innovation health. Examples of this are promoting the collaboration and networking with external partners by team members; consciously introducing new ideas into the organisation as 'food for thought' rather than fully structured initiatives, and the importance of points of failure as learning opportunities.

As a result of the research experience, the researcher has an increased awareness of the responsibility of leadership practitioners to consider the ethical implications of using a new technology. In practice, the researcher has also felt the responsibility of ensuring that the ethical implications are considered by other leaders in the organisation. When the opportunity arose to discuss artificial intelligence with the global CEO of the researcher's employer, a focus of that conversation was proposing the inclusion of an ethical framework in any development to ensure the risk of bias was adequately managed.

As a result of the professional growth that the researcher experienced by undertaking research, the researcher was headhunted by an industry leading organisation to work within a recently acquired start up, with the aim of introducing best leadership practices. The researcher applied the awareness of knowledge based behaviours to create 'knowledge maps' of the organisation, which highlighted the most impactful areas to target for change.

Ethical Considerations

In order to access meaningful qualitative data, engagement with participants is required. Dawson notes that 'the research process intrudes on people's lives' (Dawson, 2009, p. 149) and as such, care should be taken that participants are not negatively affected. Dawson recommends overt research should be chosen if it meets the research objectives, to allow participants to make informed decisions about participation. To support this, a project information sheet was produced and

provided to participants which also included details of the project supervisor, should they have any concerns.

Within the study, the topics discussed were commercially sensitive as they related to confidential information on organisational capabilities, competencies and strategic responses. Additionally, the participants' reflections on their own leadership behaviours are sensitive as they contain observations that may be detrimental to their career. To identify the appropriate ethical protections, a review of the ethical implications of the study, documented in the student project ethical review (SPER) form in appendix four, highlighted the importance of data management to ensure privacy and confidentiality are maintained. To support this, anonymity and full confidentiality should be offered to the participants. The use of an informed consent form, confidentiality and right to withdraw were included in the research script to ensure that all participants were aware of the ethical protections in place for the study. The informed consent form is documented in Appendix Three.

To meet the ethical responsibilities, the data protection policy of the third-party transcription service was reviewed to ensure that it met all regulatory requirements, and that the data would not be retained and further processed by the company. Once the transcription was complete, the researcher then manually anonymised the data by removing all names of the participants and the organisation, as well as the names of any colleagues that they disclosed prior to uploading the transcripts into cloud storage and NVivo. By anonymising prior to uploading and storing, the risk of impact to participants in case of a data breach was limited.

Additionally, consideration of the implications of interviewing participants that are employed in the same organisation as the researcher were considered and led to the decision not to include them as participants.

Research Design Philosophy

Due to the limited literature available connecting strategic leadership behaviour and Industry 4.0, this research study is characterised as exploratory. According to Sekaran (2003), an exploratory research investigation focuses on an expansive approach towards gaining knowledge of the phenomena that was not previously available (Sekaran, 2003). Additionally, Yukl states that a strong criticism of research on leadership is the lack of connectivity between research investigations (Yukl, 2009). To avoid further fragmentation, this research study aims to contribute to the existing body of knowledge by focusing on exploring the application of accepted knowledge in the context of Industry 4.0.

To adequately address the aims of the study, consideration must be given to the philosophy underpinning the research investigation and the specific methods used. The philosophy of the research design is commonly referred to by a number of terms, including the worldview (Creswell & Creswell, 2018) or the paradigm (Collis & Hussey, 2003). The philosophy of the research design is uncovered by stating assumptions made by the researcher. Creswell defined these assumptions in five key areas.

Ontological Assumptions

Ontological considerations allow the researcher to position the role that reality plays in interpreting data. The ontology of the research design is considered through both interpretivist and positivist lens; the positivist lens assumes that reality is a stable, known entity that the researcher can draw objective conclusions from without exerting any influence on the results by the act of research. The interpretivist lens posits that reality is subjective to the meaning that actors, both researchers and participants, impose on data and analysis.

In this study, behaviour is the phenomena that is being investigated. As a concept, behaviour is subject to interpretation; a recognised challenge in behavioural research is that there is no universal standard that can identify and categorise behaviour. Leadership behaviour has been heavily researched to date, with a consensus in the body of knowledge that leadership behaviour must be contextualised for valid conclusions to be drawn from data (Yukl, et al., 2019), (Yukl, et al., 2002), (Larsson & Vinberg, 2010). This precedent of contextualising behavioural data demonstrates that interpretivist research design is a robust and effective way of analysing data.

Epistemological Assumptions

According to Creswell, epistemological assumptions concern the relationship of the researcher to that research. Saunders et al defines this as 'the researcher's view on what constitutes acceptable knowledge' (Saunders, et al., 2009, p. 112) What constitutes acceptable knowledge is also shaped by what research methodologies have been used and deemed acceptable by other researchers in the field.

Table one shows the most common and uncommon research methodology used in leadership research (Yukl, 2009).

Feature	**Common**	**Uncommon**
Research Method	Survey study	Experiment
Research Objective	Replication	Explore New Issues
Level of processes	Individual/Dyadic	Group/Organisational
Time frame	Short-term	Longitudinal
Causality	Unidirectional	Reciprocal
Criterion Variables	One or two	Several
Mediating Variables	Few or none	Several
Data sources	Single	Multiple
Sample	Convenience	Systemic selection
Level of leader	Supervisor	Executive

Table 3 Common and Uncommon Features in Leadership Studies

As highlighted earlier in this chapter, the influence that the researcher holds on the research is an important consideration, particularly in qualitative research. It is acknowledged that the researcher's role in practice influences the relationship to the research phenomena, causing the relationship to be subjective but consciously so.

An alternative position has been proposed to move away from absolute views, and instead move to the focus on the collection, interrogation and integration of knowledge. (Holden & Lynch, 2004). Gordon has posited that all researchers can do is to qualify research findings as contextually explanatory and probably generalisable, rather than in insisting that findings are absolutely certain –

gathered evidence should be viewed as building bricks which aid our "cognition of the world' (Gordon, 1991).

The epistemological assumption that underpins this research design is that knowledge on leadership behaviour should be contextualised; the context that this study focuses on is the technological changes introduced by Industry 4.0. However, the researcher recognises that the complexities of the full context of leadership behaviour are unlikely to be fully available to the researcher and that the results of the study are likely to be generalisable rather than universally specific.

Axiological Assumptions

Axiological assumptions consider the role of values in the research study. In this study, the data is value-driven and biased due to the subjective nature of behaviours. Reports of behaviours will be subject to the values of the participants, which will not necessarily be made explicit. Additionally, the analysis of the data will be subject to the values of the researcher. Heron (1996) argues that 'values are the guiding reason of all human action' and therefore highlights the role that the values of a researcher play at all stage of enquiry (Heron, 1996, p. 25). Building on this assumption, Saunders (2009) posits that the acknowledgement of axiological assumptions is a requirement for research to be considered credible (Saunders, et al., 2009). Heron proposes that researchers write a statement of their own personal values (Heron, 1996). To make explicit the researcher's values that interacted with the development of the research design, a statement of values as relating to leadership behaviour follows. The statement has been drawn from the researcher's personal reflection on practice experience.

Statement of Personal Values and Beliefs

The personal values of the researcher, pertaining to leadership, are as follows

- Leadership is a position of power that affects other people on a deeply personal level. The power that a leader holds over followers is not compartmentalised to one area of the subordinate's life. A position of leadership is therefore a privilege and a great responsibility.
- Ethical use of influence and power is a central tenet of good leadership. The researcher views ethical use as considering the potential to cause harm to followers, physically or emotionally, through acts of leadership. The consideration of potential harm must be evaluated not only at the dyadic level of the leadership process but also at the team, organisational and environmental level.
- The researcher subscribes to the value ideology that good leaders are effective leaders, but effective leaders are not always good leaders. This means that having impact on followers is only one part of good leadership.
- The researcher also wishes to acknowledge that empathy with leaders is a value that is active in the decisions that have contributed to this research study. The researcher believes that leadership roles are highly emotionally and intellectually stressful, and a large part of the leader's workload is not explicit and therefore not routinely recognised. A high contribution of stress is evaluating and adapting to new challenges and opportunities, in an organisational environment where data to make fully informed decisions is not available.

Derivation of the personal values of the researcher

The personal values emerged as the result of the self-reflective practices that the researcher engages with as part of their practitioner development. The self-reflective practices originated from the apprenticeship in leadership and management that the practitioner completed. The apprenticeship was structured as a phased approach, and the first year focused intensely on the ability of leaders to cultivate self-awareness and emotional regulation before aiming to influence and lead others. The researcher learnt to use self reflection models such as Gibbs reflective model in conjunction with the application of management theory and in conjunction with feedback from peers and colleagues. By using reflective learning, the researcher could make explicit the assumptions that they bring to their practice and the associated outcomes. This connection between assumptions and outcomes allowed the researcher to challenge the assumptions and refine their underpinning values to mediate towards more desirable outcomes.

Rhetorical Assumptions

The impact of the type and style of language used throughout research is also an area to be considered in research design. The language used in the research influences the available interpretations of the data. In this study, the abstract and personal nature of behaviours leads to the language being informal and based on evolving definitions. The research objective of identifying and evaluating behaviours shows that evolving definitions of behavioural categories are to be expected, influenced by participants and researcher interpretation of actions.

Additionally, the literature review shows that the language used to describe emerging technologies in Industry 4.0 is evolving as new applications and uses are discovered. This leads to the use of metaphors and other informal phrases when the technology is being discussed.

Methodological Assumptions

The process of acquiring knowledge can be split into two mainstream, binary perspectives of inductive and deductive reasoning. Inductive reasoning uses a logical process that focuses on building theory up from data, whilst deductive logic uses hypothesis drawn from existing theory which is then tested using research data (Saunders, et al., 2009).

Both processes face critique and have recognised limitations: Konrad (2008) states that “research questions derived solely through deduction from even a thorough knowledge of the extant literature are likely to generate only incremental contributions to the field” (Konrad, 2008, p. 56). However, as discussed in the relation to theory section in the introduction, research questions derived from challenging assumptions in existing theory can lead to novel theory creation (Alvesson & Sandberg, 2011). Eisenhardt et al (2016) disagree with this, positing that inductive reasoning is the preferred pathway to identify novel theories, and that the ‘thick description’ provided in qualitative research affords this opportunity (Eisenhardt, et al., 2016). A recent assessment of methodology used in management studies concluded that ‘achieving a better balance between inductive and deductive research will, in our view, lead over time to fully fledged, broader theories and advance knowledge in management studies’ (Woiceshyn & Daellenbach, 2018, p. 189).

For this study, the research objectives can be split into the evaluation of existing theory and the identification of novel behaviours and influencing factors. Both pathways of investigation are

needed to fully answer the research question, which focuses on how leadership behaviour intersects with Industry 4.0 technologies. Investigating the validity of existing theories and models uses a deductive research process by challenging existing theory with data. Identification of new phenomena is an inductive process, highlighting emerging themes that are not yet recognised in the body of knowledge. This combination, or cycling between deductive and inductive reasoning, has been identified as a pragmatic research design by Morgan, who states that 'what is inferred from observations is converted into working hypotheses for further testing, which leads to new observations, and so on' (Morgan, 2014, p. 1047) . According to Morgan, 'pragmatism refuses to locate itself in a traditional epistemological space, and instead replaces the metaphysical dualism of realism and relativism with an entirely different worldview, which emphasizes the linkage between beliefs and action. Rather than arguing about whether something is true or not, pragmatists focus on the consequences of acting on a set of beliefs' (Morgan, 2020). Therefore, knowledge is not about an abstract relationship between the knower and the known; instead, there is an active process of inquiry that creates a continual back-and-forth movement between beliefs and actions.

In relation to the research question, objectives and positioning as an exploratory study, pragmatic methodology supports the use of inductive analysis to generate new insights, and the deductive elements of this research design maintain the links to existing bodies of knowledge. The combination of the two elements allows the researcher to seek appropriate context to the data. Therefore, a pragmatic methodology is best suited to achieve the research outcome of a bridging study between Industry 4.0 literature and strategic leadership behaviour.

Method of Data Collection

As discussed previously, the study has been characterised as exploratory, using a pragmatic design philosophy. Therefore, the selected method of data collection must capture sufficient breadth of leadership behaviour in Industry 4.0 to allow for valid analysis. To achieve this, there are several data collection methods available.

Surveys

Surveys have been used extensively in leadership behaviour research, identified as the most frequent research method (Yukl, 2009). This is often due the ease of administration of this research method when compared with other methods of data collection. However, significant limitations have been identified in using surveys to investigate leadership behaviour (Uleman, 1991). The limitations include ambiguity in research terms (Shipper, 1991), response bias (Schriesheim, 1979) and challenges in inferring causality to correlation (Yukl, 2009).

Observational studies

Observational studies occur when the researcher assumes an objective role in a scenario specific to the stated research aims. A key benefit of this method is that it does not rely on a participant self-reporting their perception of the scenario; any observations that are made come from the researcher directly (Jamshed, 2014) (Orton, 2000) . However, there are several challenges in using this method to observe leadership behaviour, reflected in the literature showing that this method has been rarely used in leadership research. One barrier is the logistical challenge that it presents to have a researcher observing a leader in the day-to-day business environment, from a commercial,

ethical and efficiency perspective. Additionally, the presence of a researcher observing the leader has been posited to affect the leader's behaviour, leading to 'presentational behaviour' (Conger, 1998).

Document Review

Document reviews can be a source of primary data that allow a researcher to infer connections between events and outcomes. Documents that have been used in previous research on leadership behaviour have been annual company reports, press releases, as well as behavioural reports generated from self-reported analysis e.g., Myers-Briggs, Insights Discovery, StrengthsFinder (Brain, 2004) (Townsend & Pisapi, 2013). The validity and robustness of these documents can be challenged due to the document originating from something other than research aims. The documents therefore require a greater degree of interpretation and are at risk of being interpreted with bias (Bowen, 2009). Recognising this limitation, document review studies on leadership behaviour have predominantly used document reviews to identify criteria of effective leadership, rather than the specific leadership behaviour.

Interviews

Interviews have been an accepted data collection method for research on leadership behaviour and have been used to interview both leaders and followers. They have also been used in conjunction with document reviews to provide identification of behaviours e.g., (Brain, 2004). Interviews can take three forms – structured, semi-structured and unstructured.

Structured	Structured interviews are predominantly used when the researcher has a very specific research question and are used to investigate an isolated dynamic.
Semi-structured	Semi-structured interviews are used to direct an investigation into a new phenomenon and allow the researcher and participant to explore new avenues of investigation.
Unstructured	Unstructured interviews are used to explore participant led areas of investigation; the focus of the interview is on the use of lived experience and participant perspective to gather data on a research area.

Table 4 Types of interview and appropriate use cases

In leadership behaviour research, Behrendt et al argue that ''leadership behavior models developed solely based on interviews and surveys share a major flaw: they fail to differentiate between leadership behavior and perceptions of leadership behavior'' (Behrendt, 2017, p. 230). However, Conger recognises that qualitative methods, such as interviews, offer context that may otherwise be missed. He attributes this to 'the extreme and enduring complexity of the leadership phenomenon' (Conger, 1998, p. 108).

The objectives of this research study are to

1. Evaluate to what extent previously identified leadership behaviours are present in strategic leader responses to Industry 4.0
2. Identify if any uncategorised behaviours are being exhibited in strategic leader responses to Industry 4.0
3. Evaluate the behaviour demonstrated by strategic leaders in response to Industry 4.0 in comparison to the enablers and inhibitors identified in the literature to date
4. Identify any additional enablers or inhibitors that are impacting strategic leader behaviours in the Industry 4.0 context

The phenomenon that is being explored is leadership behaviours, re-signified in the context of Industry 4.0 technologies. The re-signification of a phenomenon in an interpretative theorising approach means that unstructured interviews are not suitable as a data collection method, as the researcher needs to direct the questions around Industry 4.0. The study has also been categorised as exploratory, as it seeks to identify new behaviours, enablers and challenges if they are present. Therefore, using a structured interview would not be appropriate as it could restrict opportunities to gather high quality contextual data. Semi structured interviews are therefore selected as the data collection method for this study. This selection is supported in the literature; Hothschild (2009) and Gillham (2000) both support the use of semi structured interviews when interviewing participants who are categorised as 'elite'; further discussion on this categorisation is discussed in the sampling technique section (Hochschild, 2009) (Gillham, 2000, pp. 59-61).

Pilot Study

In order to ensure that the intended method of data collection was appropriate to the research aims, a pilot study was conducted with a single participant. In support of this pilot data study, a research script, project overview and informed consent form were prepared and are evidenced in appendix one, two and three. The research script was informed by themes identified in the literature. The interview was recorded in audio and video form, and then transcribed verbatim by a third-party contractor. The participant additionally provided behavioural reports that had been completed as part of their professional development.

The use of a script in the interviews is to ensure that the answers from participants can be compared, and to provide the focus on the research aims. Using Nvivo, the pilot transcription was analysed against the research script to identify if the script had achieved these objectives and if it was therefore acceptable as a tool to use.

The analysis of the pilot data excluded any affirmatory statements from researcher and showed that the researcher deviated from the script one hundred and fifty times. However, these instances were further investigated and could be coded as signposting the interview, building rapport, reflective listening and prompts relating to the initial scripted question. The remaining deviations from the script informed the subsequent refinement of the research question and aims.

The pilot study objectives focused on the Internet of Things phenomena, rather than Industry 4.0, shown below. The results of the pilot study demonstrated that the participant did not focus on the Internet of Things as an isolated concept.

Participant 1:	...and all of our, um, process lines will be automatically monitored through sensors and everything else.
Speaker 1:	Mm-hmm (affirmative).
Participant 1:	Such that, we know what's coming off the end of the line is good. Um, so it's not then automating the jobs themselves, it's automating the monitoring of the jobs themselves.
Participant 1:	...gaining all that information, you know, I know you got big data, got a lot of questions on there about big data somewhere online, but it's getting that- that, you know, that word you've got in this statement here talked about velocity?
Participant 1:	Yeah. Um, the whole real-time data, and making the visibility of all that- of that real-time data, which means you could react faster and you can learn and develop, um, you saw it as well, and, um, so, I think that's- that's really important is getting as much information as you can to inform your decision making, as a manager. Um, so, you know, if we connected up finished goods to
Participant 1:	...so wh- when you're talking about the team and it's software we're already started talk about having European... because it's cloud based and we could put it on a server-
Participant 1:	...because it all be automated, and, you could then give re-alerts to out of pattern defect rates-
Speaker 1:	Mm-hmm (affirmative).
Participant 1:	...that you'd have a re-alert, which would be automatically mailed to a relevant person to say, "this line is off in this problem at the moment"-

Figure 4 Extract from pilot study data

The extracts above were taken from the pilot data study and demonstrate that the participant was also considering cloud-based platforms, sensor application, automation, artificial intelligence and big data management. As the research design is exploratory, limiting the research questions to focus on the Internet of Things did not allow for the full breadth of the phenomena to be captured. Therefore, the pilot study led to the researcher increasing the scope of the study to cover Industry 4.0 as a concept. The structure of the scripted questions remained the same, but terminology that referred to the Internet of Things was changed to be Industry 4.0. As a result of this change, the data generated in the pilot study was not included in the investigation as it would have skewed the perspective across the dataset to be Internet of Things specific. The updated research script is documented in appendix five.

Sampling Technique

Defining what consists of an ideal sample for qualitative studies is an ongoing debate, yet the sampling technique undertaken in a qualitative study is a key indicator of the research quality (Mocănașu, 2020). The challenges to formulating an 'ideal' sample are recognised as 'availability of time and resources, the objective of the study, purpose of the study, what will affect the credibility of the study, and what will be useful' (Patton, 2002, p. 55). In addition, the purposive selection of

the participant to best understand the research problem and answer the research questions is fundamental to good quality qualitative research (Creswell & Creswell, 2018). Purposive sampling can be done along three dimensions: typical cases, extreme cases and range of variable cases (Shaw, 2014). Yukl identifies that convenience of research participant has been the predominant method of sampling in leadership research (Yukl, 2009).

In this research study, the purposive selection of the participants focused on the dimensions of typicality, with limited focus on extreme cases and a range of variable samples. The typicality was determined by the criterion used to select a participant; an executive in a multinational organisation in medium to heavily regulated private industry, such as medical, energy or aviation. The level of experience of the participant was not explicitly targeted; however, an executive role implies that there would be a similar minimum level of experience between the participants. There was also limited variability in the macro environment of the executive due to the stipulation that the organisation must be a multinational within a medium to heavily regulated industry. The use of purposive selection in this study was determined by two main factors

1) The breadth of the phenomena that is under investigation. Industry 4.0 and leadership behaviours are complex phenomena; by reducing variability in the sample, greater clarity and insight may be gained.
2) Resources available to the researcher. This factor is closely related to the convenience of selection identified by Yukl (Yukl, 2009). The researcher already had a professional network that was active within relevant industries, leading to a certain level of convenience in identifying and recruiting participants. The researcher was also limited in time and resources available to recruit a large and varied number of participants, and so the decision to reduce variability in the sample size would also allow the researcher to focus the available time on ensuring high quality of data.

The convenience or ease of access to participants as an influencing factor on the sampling technique can be further contextualised by viewing the participants as ‘elites’. Stephens (2007) defines elite participants as elite either ‘in terms of social position relative to the researcher conducting the interview in these instances, or relative to the average citizen in society, they are still clearly in a position of power and raised social stature’ (Stephens, 2007, p. 205). The target participants in this study are elite in terms of their professional and social position relative to the researcher, as well as elite relative to the average professional in their industry. This status poses challenges to access these participants, as well as naturally limiting the overall sample size available in society. However, despite these challenges, they remained the target sample due to their elite status. Goldman and Swayze (2012) state that ’simply because of their position in the organization, elites may have information other staff do not: They can usually provide a detailed overview of the organization and discuss external relationships; they are likely to be more familiar with legal and financial structures; and they are usually able to discuss organizational policies and future plans’ (Goldman & Swayze, 2012, p. 231). This level of information and contextual awareness provides high quality data to support the research aims. Literature on interviewing elites is not extensive; Odendahl and Shaw (2001) conducted an in-depth review of the literature and concluded that there is a ‘shortage of

methodological literature on applicable research practices. Guides and manuals dedicated to interview techniques seldom differentiate elite from nonelite subjects; if they do, they make cursory reference to any specialized approaches' (Odendahl & Shaw, 2001, p. 313).

The need for a specialised approach and consideration is driven by the additional challenges of interviewing elites. These challenges can be broadly split into three areas: identification, access and power (Goldman & Swayze, 2012) (Stephens, 2007) (Odendahl & Shaw, 2001). Identification and access to elites can be challenging in several different ways; elites may not invite scrutiny by researchers and employ gatekeeping techniques or personnel. Once engaged in research, elites have a recognised tendency to attempt to dominate the interview and disrupt the power balance between the researcher and interviewee. Stephens noted that there can also be several exacerbating factors, such as the age and experience of the researcher.

In order to overcome these obstacles, a range of techniques were used to access and engage participants in the study.

The first technique that was used was utilising the already professional network of the researcher. Due to the ethical considerations of conducting research on colleagues and leaders in the researcher's employing organisation, some potential participants were ruled out. Therefore, the researcher focused on their external professional network. The researcher used the professional networking site LinkedIn to identify individuals in their network who held senior strategic roles on organisations that met the desired criteria. Once identified, the researcher used the platform to send a personalised message, that showed interest in reconnecting more closely and enquiring if the participant would be interested in participating in the study. At this stage, a very short general overview of the study was provided. If a positive response was achieved, the researcher shared more specific details about the study, and highlighted the requested time commitment from the participant. If the participant agreed to the time commitment, the researcher aimed to establish a date and time for the interview as soon as possible.

Another technique used to find participants was the use of personal network for introductions to potential candidates. The researcher requested help from close friends and family in identifying strategic leaders and asked for inquiries and introductions. In this scenario, the intermediary asked the potential participant if they were interested in participating, using supporting materials provided by the researcher. If the participant agreed, their contact details were then passed to the researcher who followed up within twenty-four hours with more details about the study and requested an initial introductory phone call as soon as it was convenient for the participant. During this phone call, the researcher and participant agreed on a time and location for the interview.

A third technique that was used involved the participants self-selecting into the study, rather than being personally approached. In order to promote the study to an appropriate audience, the researcher took part in an industry conference, IOT and Industry 4.0 expo, and presented a contextual presentation on leadership and Industry 4.0. One of the aims of the presentation was to promote discussion on the role that leadership plays in Industry 4.0, and to validate the potential

impact of the research study. An additional aim was to invite potential participants to identify themselves. A copy of the presentation is shown in appendix six.

This technique was the most successful, resulting in two participants asking to be included in the study. One participant immediately approached the researcher following the presentation and a short discussion was held on the content, followed by the participant and researcher exchanging business cards with an agreement to follow up on arranging an interview. The second participant initiated contact several months following the presentation, requesting inclusion in the study.

In order to vet the candidate's suitability for inclusion in the study, the researcher ensured that the conference was aimed at a suitable audience. The data published by the conference on historical attendees showed that most of the audience would be in strategic, decision making roles. Following participant introductions, the researcher requested to make a connection with them on LinkedIn and reviewed their profiles for evidence that they met the study criteria.

Recruitment of participant sample viewed as a marketing approach

Throughout the process of recruitment, the researcher applied the principle of 'touchpoints', inspired by marketing practice and theory. The theory posits that to get potential customers to take desirable action, the promoter must create multiple, small instances of engagement that consistently support value creation for the customer. The touchpoints must be in places that are meaningful for the customer, rather than an 'everything, everywhere' approach (Hogan, et al., 2005). The customer in this instance would be the participants, and the desirable action would be engagement and participation with the research study. Opportunities to create small, consistent opportunities for engagement were structured along a pathway of increasing relationship levels. The researcher viewed the relationship with the participants as starting before the participants are aware of the researcher or the research study.

The model below shows the overview of the process undertaken to gain access to elite participants, and the key actions used by the researcher at each touch point.

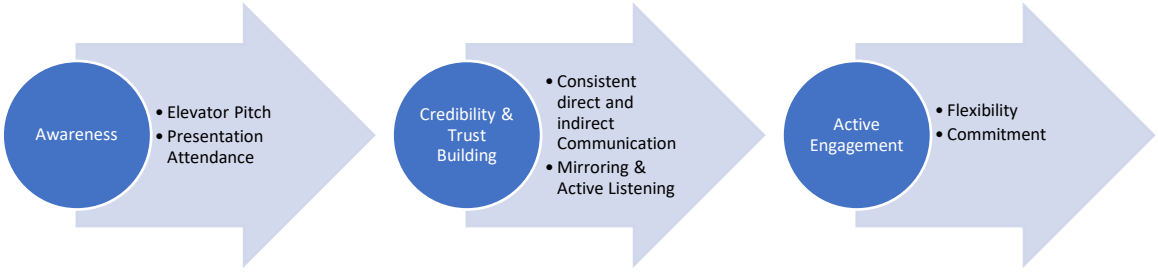

Figure 5 Model of Marketing Approach to Recruiting Elites

All participants started at the most remote point from the research study, characterised by zero knowledge of the research study. Therefore, the first engagement opportunity could be characterised as awareness, via LinkedIn message, personal enquiry or presentation attendance. A key element of success in this stage was to provide information to the potential subject at an appropriate level. To support this, the researcher created an 'elevator pitch' for the study, which was used consistently with all participants. Another key consideration at this stage was to ensure that the participants felt that they were in control and were not being pressured. The first technique ensured that personal interest was conveyed in the initial message, in addition to their value as research subjects. The second technique used a trusted intermediary, so that the researcher was 'imbued with a certain legitimacy', a technique that Odendahl and Shaw highlight as particularly effective (Odendahl & Shaw, 2001). The third technique allowed participants to decide to engage further. In addition, the focus on the professional quality of the interaction was high; some of the challenges of engaging with elites as an inexperienced researcher is building credibility and managing the elite tendency to dominate the interview (Goldman & Swayze, 2012) (Stephens, 2007). It was also important for the time commitment of the research participation to be shared in the first touchpoint; elites are recognised to be subject to demanding schedules. By sharing the time commitment at the first touchpoint, the researcher demonstrated respect for their schedules and it also allowed elites that would not be able to commit to select out of the study in the early stage, avoiding any frustration and inefficiency.

The second stage of engagement could be characterised as credibility and trust building. In this stage, the researcher focused on behaving in a way that conveyed respect and professionalism and building rapport with the participant. This varied across the three techniques. In the first technique, the use of a professional networking site, as opposed to other social media options conveyed that this was a professional request. In the second technique, the use of the university affiliated email

account instead of a personal email account for initial contact also contextualised the communication as professional. In the third technique, the researcher had professional business cards available for exchange. Outside of direct contact methods, the researcher created additional touchpoints, by ensuring that all publicly available information about the research study and researcher was up to date and professional. This included the researcher's LinkedIn profile, conference profile and the creation of a website specifically to support the research study. The researcher also aimed to respond to participants within twenty-four hours. Overall, these tactics were targeted to give a consistent and credible impression of the researcher.

After the initial contact, relationship building with each participant was focused on. The researcher aimed to have regular contact with the participant in the approach to the interview, by scheduling introductory calls and giving participants the opportunity to ask questions about the study. Through this contact, the researcher was able to get a sense of the communication style of the participant and ensured that their preferred style was used in communication. For example, one participant emailed in a direct manner, without salutation or formal sign off. In phone calls, they were also direct and eager to get to the purpose of the call. A different participant was more formal and cautious in their communication, and so the researcher responded in formal, lengthy communication.

The relationship built in the second stage of engagement was critical to ensuring that the interviews provided good quality data. The researcher was able to use the knowledge about the preferred communication style to ensure that the tone and contextualising of the research questions was maximised for effect. The trust and goodwill that had been built also allowed the researcher to challenge participants for more descriptive and detailed answers if required. Additionally, the intentional management of the researcher-participant relationship prior to data collection helped to mitigate some of the obstacles common when interviewing elites, particularly as a young, inexperienced researcher.

The sampling techniques utilised resulted in five participants that met the criteria being recruited into the study. The sampling activities were undertaken without a target number of participants, due to the overall aim of theoretical saturation in data collection. Once the five participants had been recruited, there were ongoing efforts to recruit more participants. However, at this stage in the study, the Covid-19 pandemic had been declared and the UK was in lockdown.

Impact of Covid-19

The Covid-19 pandemic was declared at a point when five participants had been interviewed for the research study, and there were ongoing efforts to recruit further participants. However, Covid-19 meant that the accessibility of targeted elites for the study was greatly decreased; many of the executives had much larger and more pressing concerns than participating in a research study. In addition to the decreased availability of participants, the researcher was concerned that any data gathered after the pandemic was declared would be fundamentally different to the data already gathered. For example, macro and micro trends that impacted the participants view of Industry 4.0 may have been impacted by their experience of managing throughout the pandemic.

However, the concern of theoretical saturation remained, as well as the validity of the data gathered pre-pandemic. To manage this risk to the quality of the data analysis, the researcher adapted the research methodology and used 'member checking' to deepen the quality of the data already gathered. The researcher contacted the participants and invited them to a follow up interview to discuss whether their insights and views had changed post-pandemic. Two out of the five participants responded to this request and took part in an interview that lasted approximately one hour. Due to the restrictions on travel, the interview took place via video call.

Participant Profiles

The research study is populated by strategic leaders in multinational private companies, operating in medium to heavily regulated industries. All participants are actively leading, or have recent experience of leading, on sites in the western hemisphere, although the companies may have their headquarters in other geographical areas. The criteria used to identify strategic leaders is defined as leaders who have the responsibility of leading the response of their functional value stream to the strategic environment. Medium to heavily regulated industries are identified as medical devices, aviation, energy infrastructure and financial institutions.

To reflect on the relationship and context of the data collection, and ultimately the quality of the data, a narrative pen portrait of the participants is provided below which includes relevant details of the organisational context. The participants have been given pseudonyms to preserve anonymity.

Organisation One:

Organisation One is a multinational organisation that has diverse business units in aviation, defence, energy and automotive industries. It operates in over forty-five different countries and has been established for over one hundred years. It is an internationally recognised brand with headquarters in Britain. Publicly available financial information show that it has posted historic losses in the previous five years and it is undergoing a large management restructure expected to deliver cost saving results.

Ned:

Ned was the first leader to self-select into the study by approaching the researcher at an industry conference. He is a strategic leader who holds global responsibility for asset management of their organisation's infrastructure. Ned's position is newly created and has not existed in the organisation before. Their job title is 'Director of Smart Buildings' and has a strong focus on the use in Industry 4.0 technology to introduce efficiencies and deliver cost savings in their area. Ned sees this as having two objectives 'the first is at a reduced cost. And the second thing is with increased levels of customer satisfaction. The folks that we serve within the business get an improved experience.' Throughout the interview, Ned consistently used descriptive language that was people based and thoughtful 'I forgot who the quote was, but it's something like smart people surround themselves with smart people. You don't need to know everything. If you trust and build a team that can.' He was keen to recognise the skills of other people and reflected openly that he has been successful because of his ability to build relationships with colleagues who have a different skill set. ''I've never

been an engineer either; I've got a geography degree I think originally. I suppose I never had that to fall back on. I've always had to use softer skills. I have relationship building, consensus building, trying to work with others to achieve common aims has always been the approach I've had to take because relying on a calculator or a spreadsheet hasn't always been an option, although I've wanted people around me that can do that work. I've been lucky sometimes''. However, Ned also acknowledged that he had good commercial awareness, although he is reserved about how successful he believes he is ''My sister's an academic and she does a lot of blue skies, if you like, research around animal behaviour, but I see the commercial application of it. She does a lot of stuff on facial structures. I'm like, "Yes, sell that to computer games industry. We're going to make a fortune out of this. I don't know whether I try, or I am practiced at looking for commercial opportunities… I've probably done it mistakenly plenty of times as well. I'm sure there's gold at the end of that rainbow and there never is.'' Ned also showed an enduring concern about the impact of climate change; he started his career as an energy management consultant. Ned is mindful of the wider trend towards sustainability, of which he was an early adopter ''I only don't feel like we are the 'green evangelists' anymore, whereas I spent probably the first half of my career being 'the green guy' and I doesn't feel like that anymore, which is really interesting. I'm kind of cool handling that mantle over''.

Organisation Two:

Organisation two is a multinational that has business units mainly operating in aviation and defence. It also has a commercial model that covers communication technology and support services. It is incorporated in the United States of America and is one of the country's largest exporters. The organisation operates in over sixty countries worldwide.

Jay:

Jay is a managing director for the UK division of the aviation systems business unit. He has responsibility for profit and loss within the division and has been in the role for less than two years. The researcher and Jay have a pre-existing working relationship. The researcher approached Jay and asked him to take part in the study. Jay is a direct communicator, who readily uses emphatic statements to describe his leadership 'I much prefer looking after money and projects than I did looking after the people.' The pre-existing relationship allowed Jay to anchor some of his descriptions in the shared experiences between the researcher and himself 'I did fancy a time in oil and gas as you know'; Jay also felt comfortable making jokes and using casual language with the researcher 'When I grow up, I think I just want to do more of what we do now, which is run large organizations'. The researcher also leveraged the pre-existing relationship to style the interview in a way that matched Jay's preferred communication; Jay enjoys a challenging debate and so the researcher felt able to push for deeper answers

> Jay: Yeah, some of this is what we discussed in the HR function. But again, I think, to a large extent, for the same reason. It is not my job and I'm not going to try to make it my job to deploy systems for HR.

Researcher: It's the HR job to get the right people into the right roles-

Jay: It is.

Researcher: ... so you're affected by it.

Jay: What makes you think I don't want to? It's just not a problem I have to go and solve today. This is ... Necessity is the mother of invention. This is about, what do I need to do today to deliver the things that I've committed to the business? And like I say, if I shave X percent ... You have to convince me how-

Researcher: You have responded beautifully to this.

Jay: That was fun.

This resulted in a fast-paced interview, with shorter, sharper exchanges than some of the interviews with participants that didn't have established relationships with the researcher. The shortness of the exchanges meant that the researcher often pushed for more descriptive language, to get the context and description required for good quality data. It is also noted that Jay readily showed emotion throughout the interview, which gave the data a rawness and authenticity that was readily accessible.

Organisation Three:

Organisation three is a multinational operating in over fifteen countries. They manufacture subcomponents for a wide range of applications in medical and aerospace industries.

Phil:

Phil self-selected into the study at an industry conference. Phil has been in his role as UK Quality Director for under a year; he was recruited to be a successor for the incumbent UK Quality Director, who was due to retire shortly after Phil's recruitment. Phil is challenged by the fact that several months after joining the organisation, the incumbent was still in role and a timeline for full role handover has not been set. ''yes, there is that sort of ... because he's still the manager, he then gets invited to all the meetings that maybe, at times, I should be at.''

Phil is able to use the time before fully stepping into the Quality Director role to put in place strategic plans for using technology to improve the organisation. He was trained as an engineer and shows an openness and motivation to learn about Industry 4.0 technologies, to the point of teaching himself how to program a raspberry pi in his free time. His focus appeared to be on the technical elements of implementation, and did not seek out wider collaborations, although he appeared open to this. '' But no, I haven't really got to that point where I've spoken to him personally about it. That's a good point, yeah, maybe it's something to actually sit down with him and explain this sort of thing. That's a very good point. I suppose it's getting to that point now, where the project that I'm working on, is to start talking, to start selling this to other parties, to get them on board''

Phil was a highly engaged participant; the interview lasted over three hours and Phil was readily able to provide rich descriptions of his thoughts and actions that he has taken and is planning to take. The length of the interview provided some challenges to maintain the energy in the discussion; however, the intensity of the interview provided good quality data. Phil also shared deeper insights towards the end of the interview when compared to the start. At the start of the interview, Phil was discussing the technical and commercial benefits of the technology but his summary remarks on the topic were profound '' I think it would be very massive for the future, and to actually ... I think we need to do that, not just for manufacturing, but just for surviving on the planet as humans we should invest a hell of a lot more in technology.''

Organisation Four:

Organisation Four is an oil and gas technology company that is privately funded but does not operate for profit. It has been in operation for several decades and provides technological solutions to customer identified issues. Any profit that is generated is invested 100% back into research and development.

Cam:

Cam agreed to take part in the study in response to a request made by the researcher's extended family. Cam had worked with the family member previously and was contacted on the researcher's behalf. Cam is the Director of Engineering and Technology for an oil and gas company and has been in the role for several years. Cam has also commercialised and sold technology previously, supported by the local university's entrepreneur's hub. Cam was a more reserved participant at first; relevant data emerged as a tangent to the discussion that the researcher had to ask direct follow up questions on. Cam is a very technically accomplished leader but was reticent to explicitly state that. He became less reserved after the researcher highlighted the reticence and showed high levels of enthusiasm for hearing more details.

> Cam: did the apprenticeship, worked for a little while, then got sponsored to go to university, then the doctorate. And also did a bit of research, a research fellowship after that, as well. So the research continued for a little while and then was into industry and application…At one stage I had a couple of honorary sort of things with RGU and Aberdeen University but I haven't done anything, worked with them for a long time now. Yeah, probably not as active. I still do a couple of papers now and then but that's enough
>
> Researcher: You're so casual about this. That's really a cool, intelligent thing to be doing. You're like, "Yeah, I just do a few papers."
>
> Cam: Sorry, I should have said, as well, actually, part of my job just now is involved in what [organisation four] calls innovation.

Cam also demonstrated a high level of self-awareness and emotional regulation, and favoured a more wry, blunt style of communication.

Cam: I think so. I think what I do know is in situations, and I've got an outcome that I maybe would like to achieve and I think I know how I should behave to achieve that outcome, but what I probably do have is I'll take a decision whether or not to behave in that way. So there is a degree of self-awareness there. Yeah.

Researcher: And that's kind of emotional regulation to be able to make a decision about how you behave.

Cam: Yes. Sometimes I just can't be arsed.

The bluntness of communication posed a challenge to getting richer detail; it was possibly an attempt at using humour to deflect the researcher from asking questions that felt too intimate. The researcher pushed for better quality data by offering an observation for Cam to agree or disagree with, acting as a pathway to continue the discussion onwards past the bluntness.

Cam: Yes. Sometimes I just can't be arsed.

Researcher: It takes energy.

Cam: It does. I think you're absolutely right. And in terms of my style, I'm quite direct and goal orientated and I understand how to get there. It takes quite a lot of effort for me to gather people round and create a team to actually achieve that. And that's probably why I'm not managing a team just now.

Researcher: But you obviously successfully did it when you had your technology development and your startup. Is that because you had a really clear goal? So the clearer the goal, the easier it is.

Cam: Yeah. I think that's a very valid observation.

The engagement throughout the interview was a slower build up than previous participants; potentially because Cam did not self-select or have a pre-existing relationship with the researcher. However, he was engaged at the end of the interview, demonstrated by the fact that he asked the researcher if they would be able to come and present the results of the study to the board of directors once it was finished.

<u>Organisation 5:</u>

The main organisation referenced in the fifth interview is an oil and gas organisation that had recently undergone a major restructure as part of an acquisition deal it executed. The objective of the acquisition deal was to expand its skill base in technical project delivery. Additionally, the participant provided consultancy work for a private equity firm and was able to provide examples of

how Industry 4.0 was influencing investment decisions in engineering companies in the oil and gas industry.

Mitch:

Prior to his recent retirement, Mitch was the CEO of the company and had held the position for several years. Mitch was recruited for the study via the network of the academic supervisors for the study. He agreed to take part in the study and arranged for interview facilities in London. Mitch had retired several months prior to the interview but remained active in consultancy work with a private equity company. Mitch highlighted the broad collaboration opportunities that he had had in his career, demonstrating that he sought out environments that had people from a range of backgrounds. ‘’was all about experience, where they put private-public senior folk together for a month. That was quite an eye opener, so that was interesting.’’

A challenge that emerged early on in this interview was Mitch’s perception of the researcher; he was aware that the researcher was a student and shaped his answers in the style of career advice for the researcher.

> Mitch: ‘’I was always asked questions around, by the graduates around, "Well, how do I progress, and how do I get on, and what's the secret to?" I said, "Well, the first thing is, you've got to remember that nobody is really going to do it for you. You really got to do it yourself. If you think you're going to get spoon-fed with a stuffing, forget it." But, if you really go after this, then there will be people that'll pique an interest…the other thing that I thought was quite key is when people talk about doing career planning, two things I'd say about that. One, is you should do it. Two, is don't expect to follow it. But the great thing about it not really working out the way that you plan it, is because you've planned it, you'll know what to do when an alternative comes up’’

This meant that the reflective, descriptive data regarding his own behaviour was harder to access. There was a definitive moment in the interview where Mitch appeared to challenge the credibility of the researcher due to their age.

> Mitch: The only thing I would ... I've never been that keen on people doing the formal education too early. You seem quite young to be doing a doctorate.
>
> Researcher: I am, yep.
>
> Mitch: Right.
>
> Researcher: So, I went from undergrad to doctorate, but I did my undergrad via an apprenticeship. I worked since 16, so I've never been to university in the traditional sense. I just work and study.

> Mitch: Well, that makes more sense, because the thing I find about when I did the MBA with there was a couple of people, it was a couple of people who effectively had never done a job.

Once the researcher had established more credibility with Mitch, the answers that he was able to provide became more expansive and met the required standard of data. Mitch was able to provide narrative examples of implementing Industry 4.0 technologies in his tenure as CEO and provided a strategic perspective on the projects that he was able to be very clear on '' big changes, but they were always a progression or adjacent to what we already did. You want to make sure you've got people to do that. It was generally internal. On the bigger shift stuff, it was a bit different''

Data Collection

The data collection took place via in person interviews, and followed the structure laid out in the research script in appendix five.

The interview environment was a corporate meeting room, used to convey environmental familiarity and professional focus. Odendahl and Shaw (2001) highlight that 'the environment where any interview takes place has a bearing on the richness of the data collected' (Odendahl & Shaw, 2001). Most of the interviews took place at the organisation where the participant was employed; in one instance, the participant arranged for and paid for a central London meeting facility for the interview. Stephens notes that a benefit of interviewing elites is that they often have access to good quality environments (Stephens, 2007). The interview was recorded using audio and visual equipment, with the equipment set up as unobtrusively as possible. Where appropriate, the researcher prompted the participant for a more detailed description and used active listening techniques, such as mirroring body language and style of language, as well as rephrasing and repeating back some answers to the participant. This led to greater clarification and depth in the participants answers. On average, the interviews lasted two hours each, and each participant was encouraged to contact the researcher if they had identified any further data that they wanted to contribute to the study. The researcher also offered to send the transcript of the interview to the participant pre analysis to allow for further elaboration or correction if the participant deemed necessary.

Out of the five participants, one emailed further clarification after the interview. One participant did not respond to the transcript but did respond with documents that supported examples he had given in the interview, with permission to use them in the research study. A third participant responded and asked the researcher to hold a workshop at their organisation on Industry 4.0. The remaining two did not respond.

Two out of the five participants responded to the request for a second interview; this took place over a video call. The second interviews were also semi-structured, with the researcher highlighting specific parts of the first interview and asking for the interviewee's perspective post-pandemic. The video call did not noticeably affect the quality of the interview; both participants were open and engaged. However, the recording equipment failed for one of the interviews and so a transcript was

not able to be generated. Due to this, data collected in this interview was not able to be directly included in the analysis. However, the researcher was taking shorthand notes of the themes discussed throughout the interview and these observations are included in the findings.

Data Analysis

In a qualitative study such as this, the validity of analysis of the data is crucial. As highlighted, qualitative research is closely intertwined with the researcher's perception and experience of reality. Maguire and Delahunt state that 'the qualitative researcher is often described as the research instrument' (Maguire, 2017, p. 33512). Commonly used methods of qualitative data analysis include grounded theory, narrative analysis, and discourse analysis.

Several methods exist for processing text and have been developed to allow the researcher to assign meaning to the data that can then be analysed. Determining how to assign meaning can take many different forms, and it is the difference in this step of data analysis that divides the methodology. Discourse analysis is a method that focuses on interpreting meaning in the semantics of the language used in the textual data. This method requires that the researcher is an expert in a community's language and take the ontological position that language creates reality (Braun, 2012). The researcher for this study is already familiar with the business community's language. Therefore, discourse analysis was considered as an appropriate method for this study. However, the population of the study is drawn from different organisations, all of which would have different cultures and dialects of business language or 'business jargon'. Access to the subtleties that inform the dialects would not be available and so a suitably rich interpretation would be unlikely to be achieved. Additionally, it is recognised in behavioural research that participants' perceptions of their own behaviour can be flawed and presented in an aspirational manner. In this instance, this weakness undermines the ontological outlook that discourse analysis would require, as it is likely that the reality of the situations and behaviours described are not absolutely defined by the participant's description.

Thematic analysis is described as 'a method of systematically identifying, organizing, and offering insights into patterns of meaning (themes) across a dataset' (Braun, 2012). This focus of analysis across datasets is what sets it apart from other qualitative analysis methods.

For this study, thematic analysis was chosen as the method of data analysis. The key reasons for this decision are

1) Thematic analysis allows the systematic review of data that can then be linked to wider, more conceptual themes (Braun, 2012). This aligns with the positioning of this study as being an exploratory bridging study between knowledge of leadership behaviours and knowledge of Industry 4.0.
2) Thematic analysis is positioned as a method of data analysis that is not wedded to any strata of philosophical positioning (Houghton & Houghton, 2018). This aligns with the outlook of the researcher, whose previously evaluation of the philosophical approaches available identified that a pragmatic approach was most appropriate.

3) Thematic analysis is also recognised as being a more easily accessible method of data analysis, and therefore an appropriate choice of an early career researcher (Braun, et al., 2014).
4) Thematic analysis allows inductive and deductive themes to emerge from the data, in line with the research aims (Ryan & Bernard, 2003).

The data analysis was divided into open and structured coding, in phases related to the respective inductive and deductive research aims.

Data Analysis Steps

The software program Nvivo was used to complete the initial coding of the data. This section discusses how the inductive and deductive analysis of data was completed. Examples of the output of the coding is in Appendix Seven.

1. In order to evaluate to what extent previously identified leadership behaviours are present in strategic leader responses to Industry 4.0, the literature was reviewed, and the most recent behavioural taxonomies identified. For this study, Yukl's 2012 behavioural taxonomy was selected as the most appropriate framework. The taxonomy is hierarchal, which was relevant for data coding. In the initial step, the individual behaviours were used as themes that data could be coded against. The definition, aim and examples of behaviour were defined as part of Yukl's work, and so were used as the criteria for coding. This step was repeated using the criteria of the behavioural meta categories. This is deductive.
2. In order to identify if any uncategorised behaviours are being exhibited in strategic leader responses to Industry 4.0, the transcripts were open coded for reference to behaviours that had not been directly related to the established taxonomies. Included in this step were data that discussed the objective of the behaviour and what the participant hoped to be different after they had taken the action. This is inductive.

As part of the data and findings chapter, a cross analysis of the data from the first two objectives was completed. The cross analysis showed that some behaviours were being demonstrated with a different objective to the stated aim in Yukl's taxonomy. The uncategorised behaviours were also evaluated against the meta category descriptions and aims, with the finding that there were new behaviours that were suitable for the existing metacategory definitions. Finally, new behaviours that did not fit the criteria of any of the existing metacategories led to the proposal of a new metacategory.

3. In order to evaluate the behaviour demonstrated by strategic leaders in response to Industry 4.0 in comparison to the enablers and inhibitors identified in the literature to date, a thematic review of the literature identified enablers and inhibitors. This list of factors were usedto code the transcripts for evidence that these themes were present. This is deductive.
4. In order to identify any additional enablers or inhibitors that are impacting strategic leader behaviours in the Industry 4.0 context, the transcripts were open coded for any enablers or inhibitors not directly referenced in the literature. The analysis also sought to identify deeper or more specific insight into enablers and challenges. This is inductive.

Data Management Plan

The figure below shows the overview of the process used to manage data collected in this study.

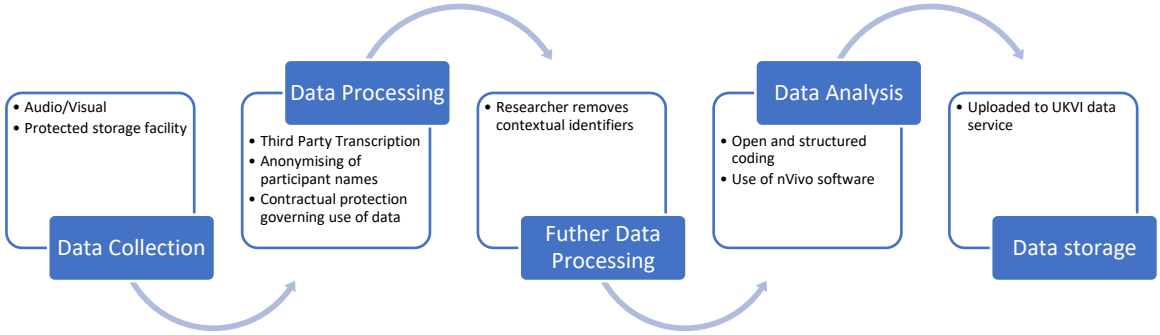

Figure 6 Figure depicting data management with research study

The data transcription step was outsourced to a transcript company, Rev.com. This was done to allow the researcher to balance their time commitments and still get the data processed in a timely manner. The third party was reviewed to ensure that confidentiality and data protection standards were in place prior to data being provided for processing. The researcher also evaluated the quality of the transcript when it was returned by checking it against the data file, and in one instance, returned the file for further processing as the transcript quality was poor.

Overall Evaluation of Research Approach

The design of the research study most suited to meet the aims of the investigation has been considered, including making the philosophical assumptions explicit. The philosophical assumptions align with the theoretical positioning of the study, as well as the practice influenced perspective of the researcher. The design also accounted for the availability of resources to support the study, including the availability and accessibility of participants, the skills of the researcher, and the time and financial investments required. A summary of the design choices made, in comparison the most and least commonly used for leadership behaviour studies, is shown in the table below.

Feature	**Common**	**Uncommon**	**Research Study Selection**
Research Method	Survey study	Experiment	Semi structured interview
Research Objective	Replication	Explore New Issues	Explore new issues
Level of processes	Individual/Dyadic	Group/Organisational	Individual

Time frame	Short-term	Longitudinal	Short-term; reflective
Causality	Unidirectional	Reciprocal	Reciprocal
Mediating Variables	Few or none	Several	Identified as 'enablers and challenges' in the research study
Data sources	Single	Multiple	Single
Sample	Convenience	Systemic selection	Systemic selection, moderated by convenience
Level of leader	Supervisor	Executive	Executive

Table 5 Research Study Choices, in comparison to the most common and uncommon

As a result of decisions made in the design of the research, inherent limitations exist. The limitations of the research design are introduced at the philosophical, data collection and data analysis stages.

The standard of qualitative research should be assessed against the criteria of credibility, confirmability, and transferability (Malterud, 2001) (Fossey, et al., 2002). The following section examines the research design against these three criteria to evaluate its' robustness. . Additionally, the decisions and methodology selected by the researcher prior to data collection aim to gather "good data". The criteria for good data is symbiotic with the planned methodology. In this exploratory study, thematic analysis was the planned method of data analysis, collected via semi structured interviews. The hallmarks of "good data" in this study were expansive answers by participants, that were broad and deep in their information and contextualisation. "Good data" goes beyond a direct answer to a direct question. "Good data" can be recognised by the participant sharing their lived experiences, observations and reflections on decisions and actions taken in the social, structural, and cultural context of their organisation. The interviewees provided rich and insightful data, that often went beyond the scope of the prompting question.

Study Confirmability

The confirmability of a study relates to the level of objectiveness within the research design. As previously identified, an interpretivist approach to the research philosophy has been selected. This approach has been selected due to the subjective nature of the phenomenon being examined, as well as the impact of the researcher's worldview as part of the data analysis. As such, there is only a limited amount of objectiveness present in the research design. However, this is somewhat compensated by using standard leadership behavioural definitions to examine the data, so that consistent interpretation of data can be claimed. This supports future researchers who may seek to confirm the findings.

The study is also characterised as exploratory; the objectives seek to challenge the assumptions inherent in existing theory, and to deepen the insight into Industry 4.0 and Leadership Behaviour available in the body of knowledge. It is not an explanatory study and does not have underlying assumptions of a unifying pattern between all leadership behaviours and all facets of Industry 4.0.

Therefore, confirmability is less of a determining factor in the quality of this study, as it relates to the achievement of the research objectives. Any exploratory connections made are valid, as they represent the true interpretation of the researcher, who is acting as the research tool.

Study Credibility

The credibility, or the reliability, of the study findings is a key measure of the research exactness (Mocănașu, 2020). To establish credibility, an examination of the method of data collection and analysis is required, including the sampling technique. Although the literature on sample sizes for qualitative studies does not have a prescribed approach, the sample size is recognised as a key contributor to the quality of the research. Therefore, an assessment of the sample size must be made to determine if it is 'proper'. Mocănașu notes that there are a 'plurality of factors – scope of research, type of approach, epistemological attitude, researcher's experience, the journal where they publish, financing, time, perception of study assessors' expectations, etc' (Mocănașu, 2020, p. 182) that affect the determination of whether a sample size is proper or not. These factors can be divided into factors 'relating to epistemological-methodological considerations and parameters related to practical research considerations', with researchers directed to give more consideration to those factors in the first category (Flick, 2012, p. 27).

Within the methodology of this study, the participants were recognised to be 'elite', defined as 'elite in terms of social position relative to the researcher conducting the interview in these instances, or relative to the average citizen in society, they are still clearly in a position of power and raised social stature' (Stephens, 2007, p. 205). Therefore, the accessibility of these participants was a challenge; however, the information they could provide relevant to the research aim remained valuable. In such a situation, "a small number of cases or subjects may be very valuable and may represent a proper number for the research project'' (Adler & Adler, 2012, p. 9). Adler and Adler go on to suggest six as a target number for studies with poorly accessible participants.

In this study, five participants were interviewed. Data gathered from these participants was extensive, and richly descriptive, which supported the thematic analysis used to analyse it. Extensive, descriptive data was the outcome of building trust with participants prior to the interview, as well as leveraging the credibility that the researcher has as a practitioner. However, the Covid-19 pandemic was declared at that point in the study. This had the impact of making the participant population completely unavailable for engagement in the study, as executives turned their full attention to mitigating the pandemic impact on their organisation. Within the already recruited group of participants, two out of the five participants were put onto furlough. If the Covid-19 pandemic had not been declared, efforts to recruit would have continued. Considering the pandemic, the researcher reviewed the sample already collected to see if it would be proper enough to meet the research aim. The sample group included a range of perspectives on Industry 4.0, a range of executive experience and variance in the educational background of the executives. As the sample group contained a broad range of data, it was determined that it would be satisfactory for the purpose of the study. The impact of Covid-19 on the credibility of the data gathered so far was a concern, and so the researcher arranged secondary interviews with willing participants to test whether the primary interview data remained relevant.

There was no representation of women within the sample. A review of the literature did not highlight any impact of gender on leadership behaviour or assumptions made in existing theory related to gender and leader behaviour, and so the exclusion of women in the sample size was viewed as an acceptable limitation.

Study Transferability

'Transferability is a key component of qualitative research, which provides us the opportunity to establish whether the research output can apply to other contexts or not' (Mocănașu, 2020) p182. The limitations on transferability in this study relate to the smaller sample size; the participants represented their own perceptions of their behaviour and so the generalisability of the study findings to other contexts is limited. It is further limited by the interpretative nature of the relation to theory, and the interpretivist method of data analysis.

Chapter Four: Data and Findings

Introduction

In order to answer the research question 'How do strategic leadership behaviours intersect with Industry 4.0?', semi structured interviews were used to collect data. Yukl's 2012 hierarchal taxonomy of leadership behaviour was used as a framework to signify the data in the context of themes identified in Industry 4.0 literature. The research objectives for this study are

1. Evaluate to what extent previously identified leadership behaviours are present in strategic leader responses to Industry 4.0
2. Identify if any uncategorised behaviours are being exhibited in strategic leader responses to Industry 4.0
3. Evaluate the behaviour demonstrated by strategic leaders in response to Industry 4.0 in comparison to the enablers and inhibitors identified in the literature to date
4. Identify any additional enablers or inhibitors that are impacting strategic leader behaviours in the Industry 4.0 context

This chapter combines the data analysis and findings together. Following an overview of participants and a statement of criteria for findings, the chapter moves into analysis structured around the research objectives. For objective one, data is analysed using the meta-categories and behavioural subcomponents defined in Yukl's behavioural taxonomy. Following the analysis, the evaluation of the extent that relevant behaviours are shown is included at the end of each meta-category analysis. Objective two analyses the data for uncategorised behaviours and groups them thematically. Objective three compares the enablers and challenges associated with Industry 4.0 to evidence provided by data. Objective four identifies novel enablers or challenges, as well as further clarification to known enablers and challenges. The chapter concludes with a cross objective analysis linking the behaviour shown to the factors within Industry 4.0 and discusses how the behavioural taxonomy could be updated to reflect these findings. Novel findings in the enablers and challenges are also summarised.

Overview of participants

The participants had differing levels of interactions with Industry 4.0 projects. The pen portraits in the previous methodology chapter highlights that the participants level engagement varied between resistance, passive or project champion. Ned and Phil had active projects that they were championing; Jay had benefited from artificial intelligence and Big Data collection in the organisation recently but had no active engagement; Cam and Mitch used Industry 4.0 technology in projects but resisted the viewpoint that the use of the technology was a goal in itself.

Criteria for findings

The criteria for the findings for each objective are shown in table four. The criteria for behaviour findings are aligned with the criteria identified by Yukl when the hierarchal taxonomy was developed (Yukl, 2012). The taxonomy was developed with the aim to integrate and consolidate the available

literature on leadership behaviour and has been accepted by other researchers as a suitable tool to connect future research findings (Borgmann, et al., 2016).

Research Objective	Criteria for findings
Evaluate to what extent accepted leadership behaviours are present in strategic leader responses to Industry 4.0	Descriptive statements of behaviours, processes or situations that can be directly linked to the leadership behaviours in Yukl's taxonomy
Identify if any uncategorised behaviours are being exhibited in strategic leader responses to Industry 4.0	Descriptive statements of behaviours, processes or situations that cannot be directly linked to the leadership behaviours in Yukl's taxonomy. Data may be linked to a metacategory in the taxonomy.
Evaluate the behaviour demonstrated by strategic leaders in response to Industry 4.0 in comparison to the enablers and inhibitors identified in the literature to date	Descriptive statements of behaviours, processes or situations connected to Industry 4.0 activities that relate to enablers or challenges posed in Industry 4.0 literature
Identify any additional enablers or inhibitors that are impacting strategic leader behaviours in the Industry 4.0 context	Descriptive statements of behaviours, processes or situations connected to Industry 4.0 activities that have not been documented as enablers or challenges in Industry 4.0 literature. This includes consideration of the level of detail included in the data in comparison to the themes in the literature.

Table 6 Criteria for findings

Evaluate to what extent previously identified leadership behaviours are present in strategic leader responses to Industry 4.0

In this section, data from the participant interviews is evaluated against the criteria for leadership behaviours as identified in the hierarchal taxonomy.

Task-based behaviours

The first meta-category identified in the taxonomy is task-based behaviour. The key goal for task-based behaviours 'is to ensure that people, equipment, and other resources are used in an efficient way to accomplish the mission of a group or organisation' (Yukl, 2012, p. 69). Within this category, four specific behaviours are defined: clarifying, monitoring, planning, and problem solving.

Clarifying

Clarifying behaviours aim to 'ensure that people understand what to do, how to do it, and the expected results' (Yukl, 2012, p. 70). Observable behaviours include setting objectives and priorities around important role responsibilities, encouraging searches for task efficiencies and providing benchmarks to evaluate performance against.

In response to Industry 4.0 technologies, the participants displayed clarifying behaviours as they sought to define and communicate their aims for how the technologies are used within their function and organisation.

Cam used the word 'theory' to communicate his plan for technology usage, and where he expected the organisational benefit to arise. The word 'theory' implies that he is not able to fully able to define at specific task level how to use the technologies, however he is searching for opportunities for task efficiencies.

The theory being that if you've got a fully sensored installation with truly tuned diagnostics and you understand everything then you can put your people where it's really important. It definitely improves ... The theory is it definitely improves productivity because you're not focusing on the equipment or activities and don't need it.

Cam

Cam also focused on efficiency as part of utilising Industry 4.0 technologies; however, he also spoke of the need to ensure that there is efficiency within the application of technologies. He was also the only participant to discuss the benefit to customers, as well as the organisation.

all that data that's collected, or information that's collected, using that... collecting it as efficiently as possible and then using that data to bring some, I guess, insights to both customers and [organisation].

Cam

Mitch also shared a customer centric approach to the expected outcome that he wanted to see.

Ultimately, for clever solutions where you can still actually earn as much on fees, but actually reduce the cost for the customer.

Mitch

Jay shared the view that Industry 4.0 will drive efficiency in the organisation, however he expanded his view to share how he would plan to measure efficiency improvements. He also foresaw that the way the organisation behaved would be impacted, as faster decision making could be possible.

it's true that the type of technology that we develop, it is in the future, going to require us to be more efficient and effective, and decision-making speed will drive us in that particular direction.

It might be a vehicle for taking a percentage cost base out in the future. It might be a vehicle for improving the speed of decision making

Jay

Ned also forecast efficiency through use of Industry 4.0 technologies, however his statement '*It's doing everything that you could possibly want to do'* is striking in its breadth and lack of clarity. He was able to give examples of the types of efficiencies he was expecting to see, albeit they were quite generalised. Ned appeared to have a great sense of urgency and belief in the efficiencies that could be generated by using Industry 4.0 technologies but struggled to articulate them in a clear manner. The efficiencies that he did discuss are areas that are commonly targeted within Lean Management and Six Sigma methodologies.

If you look at the opportunity, it's about faster, it's about more certainty, it's about improved response because of data. It's like life on steroids, right? It's doing everything that you could possibly want to do.

if there are quality, right first time, wastage improvements available to us from 4.0 then we need those now, not tomorrow really.

Ned

The clarifying behaviours demonstrated by the participants in the context of Industry 4.0 focused on their efforts to clarify the usage of the technology and the expected outcome from the application within their organisation. No participant was able to give specific examples, suggesting that the clarification remains superficial. The examples of expected outcomes focused on increased efficiency and productivity within the organisation, through better use of resources and personnel, as well as faster and more robust decision making. These types of efficiencies involve the exploitation of existing processes and are commonly known in management practices due to the influence of Lean and Six Sigma methodologies. Therefore, none of the participants foresaw innovative, disruptive efficiencies as a result of applying Industry 4.0 technologies. Jay was the only participant to provide clarification of the measurable impact he would expect to see as an outcome, in financial terms.

It is also notable that the participants focused their clarifying efforts on the application of technologies within the organisation, rather than embedding the technologies within their product or service offering. Cam came closest to suggesting that the technologies could be applied to give a competitive advantage when he proposed that the insights generated could benefit customers as well. Mitch thought that the cost efficiencies of the technology could be shared with the customers, while the service fee offering would remain the same, therefore increasing profit for the organisation.

Overall, clarifying behaviours were demonstrated but remained superficial despite participants demonstrating great enthusiasm and belief in the benefits of utilising Industry 4.0. Possible reasons for the lack of clarity are explored further in this chapter as part of reviewing the inhibitors and enablers that the participants face.

Monitoring

Yukl et al state that 'monitoring involves gathering information about the operations of the manager's organisational unit, including the progress of the work, the performance of individual subordinates, the quality of products and services, and the success of projects or programs'. (Yukl, 2012, p. 70)

The participants in this study shared that monitoring behaviours are part of their responsibilities without the use of Industry 4.0 technologies. However, their planned application of Industry 4.0 technologies also focused on monitoring; the leaders in this study would utilise Industry 4.0 applications to either directly replace their monitoring responsibilities or to make them more efficient.

We can save a lot; we can potentially win a hell of a lot more work if we can use it and get it right. And improve our quality, being on the quality side of things, the potential to have that improvement. […]it would remove one man per shift stood on the production line doing that check where a robot would come in and do that.[…] Collect data and you can improve your, reduce your process time, your lead time and then predictive maintenance, all that sort of, many benefits.

Phil

Additionally, monitoring behaviours within the taxonomy are identified as leadership behaviours; however, some of the participants highlighted the overlap between their monitoring responsibilities

and their customer's expectations and desires. A customer is concerned with progress and quality and is likely to display behaviour to seek further information. Cam and Phil proposed that Industry 4.0 technologies could be used to give greater visibility of the information gathered, and therefore reduce their management burden.

I think it'd be beneficial as well to actually ... we'd have to have a pros and cons, weigh it up, but to be able to show that customer order, where it is in the factory

Phil

Not so much because we've actually got equipment that's sensored up but having access to data from the broader Industry 4.0 would help us with our future plans and also help us service customers better.

Cam

The participants demonstrated monitoring behaviours in their role without using Industry 4.0 technologies and focused on the opportunity to apply the technologies to expand their monitoring capabilities without manual intervention, therefore either reducing their leadership burden or increasing the quality of the data that they gathered.

There was no evidence of monitoring behaviours in relation to the adoption of Industry 4.0 technologies within their organisation. The participants did not know what specific technologies were already being used, beyond some small pilot projects that were ongoing.

Planning

This behaviour relates to the cognitive effort required to identify and plan the scope and execution required to support organisational activities. It becomes observable via activities such as 'deciding objectives and priorities, writing plans, preparing written budgets, developing written schedules, assigning resources and meeting with others to determine how to accomplish a task' (Yukl, 2012, p. 70).

Most participants in the study demonstrated elements of planning behaviours, by preparing written analyses of the investment and benefit required to utilise Industry 4.0 technologies. They also identified and planned which events to attend to gather information about Industry 4.0 technologies.

But what I will do for you [Ned's manager] is figure out what use cases we can meet through the application of this technology, figure out the costs and benefits of doing so, and then implement it in a programmatic way.

Ned

Ned also described a specific Industry 4.0 tactic within his plan; he was working with his technical colleagues to ensure that the new network had excess capability against current demand so that future adoption of yet unknown technologies would not be prevented by lack of network capability.

leave a load of spare capacity in that PoE network, so when we've got our head straight on what we really want to do, we'll be able to go back and put that in.

Ned

By showing this behaviour, Ned aims to mitigate the superficial clarity on technology application and proactively address a potential future issue. The primary behaviour is planning, and there is also secondary relevance for the goals of the clarifying and problem-solving behavioural components of task-based behaviours.

Yukl highlights that each behavioural component within the taxonomy can have negative forms. Negative forms of planning behaviours are shown when the planning is superficial or unrealistic (Yukl, 2012, p. 70). These negative forms were displayed by Jay; his planning behaviour drove disengagement with Industry 4.0 technologies. The focus on achieving the short-term objectives of the organisation prevented him from investing the time and effort required to understand the technologies and their potential applications in the organisations.

What makes you think I don't want to? It's just not a problem I have to go and solve today. This is ... Necessity is the mother of invention. This is about, what do I need to do today to deliver the things that I've committed to the business?

Jay

It could be argued that Jay is accurate in his viewpoint that the Industry 4.0 technologies are not relevant for his organisation; however, throughout the interview he acknowledged that the technologies were already present due to customer expectations, but that there was a lack of understanding about how to use the data in a meaningful way. Therefore, his planning behaviours are unrealistic as they do not respond to the customer expectations and superficially focus on short term objectives at the expense of the longer-term outlook.

I wouldn't say it's a differentiated force, that's where the industry has moved. So, it's an expectation that that's what we do, too.
we have not got our arms around how we're going to use that data. The aircraft will suck up multi terabytes worth of data when it's flying, and we haven't, how do we analyze that, in a meaningful way, to go in for tomorrow's issues

Jay

Problem solving

Also known as ‘crisis management’, problem solving behaviours are demonstrated when leaders address the ‘disruption of normal operation and member behaviour that is destructive, illegal or unsafe’ (Yukl, 2012, p. 70). The behaviour can be ‘proactive or reactive; effective leaders take the initiative to identify likely problems and determine how to avoid them or minimise their adverse effects’ (Yukl, 2012, p. 71).

The participants viewed Industry 4.0 technologies as an opportunity to lower organisational risk by identifying risks more easily and at an early stage, where they thought it would be cheaper and less complex to mitigate.

being able to identify flaws or things that needed maintained right upfront would start better than coming into a major issue, nevermind the risk and the liability if it was really bad. But, actually being able to do that and intervene quite quickly, it's just very, very cost effective.

Mitch

I think there's a common misconception amongst many entities that if you sensor instrument up your equipment you never have a failure. That's obviously not the case. You always have failures. You're just intervening before they end up being a catastrophic event. Simply by instrumenting it up it doesn't mean you're not going to have to go in, work on equipment, and have people there. You're just going to have to do that a bit sooner.

Cam

However, Cam had concerns on the difficulties of quantifying the value of risk mitigation.

I think also you're kind of proving a negative, aren't you? To some degree, you're saying that by the adoption of industry four technology you won't see this thing that's happened. In instances where you've applied industry you can't demonstrate ... It's hard to demonstrate that things would have been worse if you hadn't done it.

Cam

One area of discussion was the potential problems caused by a data or system breach of Industry 4.0 technologies and the consideration participants gave to cyber security. There were some expressions of cynicism about how real the threat would be, and the participants did not seem unduly concerned about the cyber security requirements or potential ramifications of a breach.

On the one hand, it's hugely important around managing the data and security, and the data. On the other hand, it is a scary place that is consultants trying to scare you into buying all sorts of stuff, and the right place is somewhere in the middle of all of that. I think it also depends on the business that you've got. If you're heavily, heavily R&D then it's all about protecting that. If you've got lots of external customers or you're dealing with the public, the right data protection, and around all of that.

Mitch

Ned alluded to the risk that could be created to existing company assets by introducing a technology that made them less secure.

It stops me from putting something in and having all of our corporate intellectual property stolen.

Ned

This was planned to be mitigated in two ways; by having all relevant approvals for the technology before implementation, and by implementing the technology on a separate network that was disconnected from key data assets for the organisation.

The participants demonstrated problem solving behaviours by proactively seeking to identify potential issues that could arise through the use of Industry 4.0 technologies. Due to the organisations having limited use of the technology in the organisation already, no participant could give an example of addressing disruption caused by Industry 4.0 technologies or addressing disruption by using Industry 4.0 technologies.

Discussion of the extent that task-based behaviours were exhibited

Yukl states that the goal of task-based behaviours is to achieve 'high efficiency in the uses of resources and personnel, and high reliability of operations, products and services'. This objective can be achieved by a single task-based component behaviour or in combination with other component behaviours in the taxonomy.

In response to Industry 4.0 technologies, participants demonstrated elements of all the components of task-based behaviours. They used clarifying behaviours to define their objectives and expected outcome of Industry 4.0 technology utilisation to a moderate extent, limited by their knowledge and experience of the technology. These clarifying behaviours were self-directed; they were clarifying for their own benefit, and in some cases, for their management. They did not share any examples of clarifying for the benefit of subordinates. Yukl's taxonomy does not specifically state that the task-based behaviours must be directed at subordinates for the behaviours to meet the criteria for leadership behaviour; stating that 'many of the behaviours emphasize leader influence on collective processes, rather than on dyadic processes' (Yukl, et al., 2002, p. 29). However, the formation of the taxonomy was based on research conducted from 1950-1980 that 'focused on explaining how leaders influence the attitudes and performance of individual subordinates' (Yukl, 2012, p. 67). Therefore, the specific behaviour components identified in the task based meta-category have a dyadic perspective, due to the methods and perspectives used in the original research. This was 'obtained from subordinates who had little opportunity to observe their leaders interacting with people outside the work unit' (Yukl, 2012, p. 67) . Data collected in this study suggests that clarifying behaviours can be demonstrated by leaders, without interaction with subordinates.

The extent of clarifying behaviours was limited, with the participants failing to articulate at a specific level their specific objectives for Industry 4.0. The literature shows that clarifying leadership behaviours can improve the performance of a group (Locke & Latham, 1990), which would suggest that the lack of clarity demonstrated by the participants would impede their adoption efforts. The barriers that the participants are facing to gain clarity are discussed later in this chapter.

The participants demonstrated planning behaviours by writing proposals, scoping the tasks required for technology adoption and defining actions that needed to be taken to progress the adoption of the technology. However, the level of the specificity in the plans was superficial and this was recognised by the participants. The plans for Industry 4.0 adoption were viewed as being at an early stage, and best suited to pilot or proof of concept projects before formulation into an organisational wide plan.

Monitoring behaviour was demonstrated to a lesser extent, in part due to the immaturity of the plans and use of technology. However, it emerged that the importance of monitoring was clear to the participants, demonstrated by their focus on the application of Industry 4.0 technologies to provide monitoring capabilities that would either replace human behaviours or expand the scope of existing monitoring practices.

Problem solving behaviour was also demonstrated by the participants; the participants proactively sought to identify areas of risk that adoption of the technology could bring into the organisation. The extent of problem-solving behaviours was limited, due to the superficial and conceptual nature of the plans for adoption and utilisation.

In addition to the demonstration of task-based behaviours, the participants intentions for using the technology appeared to be aligned with the behavioural components of the task-based meta-category. The planned utilisation of the technology would heavily support or replace the leadership

behaviours associated with clarifying and monitoring. The concept of leadership behaviours being replaced by technology has been explored in the literature, with some evidence that transactionally based behaviours can be achieved as well as or better by an automated leader (Derrick & Elson, 2018). In this study, the leadership behaviours were subordinate focused and identified as goal setting, performance monitoring and performance consequences. The author did not connect these behaviours to Yukl's taxonomy; however, clarifying behaviours have goal setting as an observable criteria and performance monitoring is an example of monitoring.

Overall, the participants demonstrated strong task-based behaviours as they sought to adopt Industry 4.0 technologies to increase efficiency and reliability. They particularly spoke of the increase in productivity that would be achieved through more efficient resource management. Resources were materials and people, and a common theme was being able to combine the two types of resource in an efficient manner. The quote from Mitch below demonstrates how the component behaviours combine to achieve the overall task-based goal.

''I think that there needs to be an improvement around the alignment through the projects, where designs are really complete, and materials and equipment are really complete.''

This element shows the importance of clarification of objectives and defining what 'complete' means, as well as alignment.

''Then, the individuals where you've got a large manual interface, basically the manual interface needs to have a definitive plan, a completed design, the materials on hand''

This element demonstrates the planning contribution.

''and everything there ready to do the work''

Monitoring of the status of inputs is also part of this perspective.

''and that's where productivity will actually increase.''

In this example, no problem-solving behaviour was required as the three other component behaviours had been demonstrated to the extent that there were no problems to solve.

The key finding is that task based behaviours are present and demonstrated consistently in response to Industry 4.0. The task based behaviours are seen in actions that the participants are taken as well as how they forecast the utilisation of technology to support task based leadership in the future.

Relations-based behaviours

The second meta-category in the hierarchal taxonomy is relations-based behaviour. The key goals for relations-based behaviours are 'to enhance member skills, the leader-member relationship, identification with the work unit or organisation and commitment to the mission' (Yukl, 2012, p. 71) Specific relations-based behaviours are defined as developing, supporting, recognizing and empowering.

Developing

Developing behaviours are used to 'increase the skills and confidence of work-unit members and to facilitate their career advancement' (Yukl, 2012, p. 71). Overall, developing behaviours are closely linked to coaching subordinates, but can also include providing development opportunities by

assigning tasks to expand skills and making it easier for subordinates to attend learning workshops or courses. Additionally, Yukl notes that developing can be used with peers or 'an inexperienced new boss' (Yukl, 2012, p. 71).

Phil showed developing behaviours towards colleagues who were subordinate to his level, but not his direct reporting responsibility. He identified that some subordinates were threatened by the adoption of Industry 4.0 technologies, caused by fear about the stability of their employment. He proposed providing training for the teams to expand their skills and knowledge.

it's not just the senior management team but people who work on the shop floor, the technicians and everyone, because they think they're going to lose their jobs. It's helping them to embrace it and understand it, and I think a lot of training or informing them somehow of the benefits.

Phil

Phil also showed developing behaviours towards his senior management team; he recognised that he would need their support for his proposed changes but faced challenges with their level of knowledge of the technologies and their potential applications within the organisation.

Lot of it is people's understanding of what it is and persuading people that it's not pie-in-the-sky ideas, and it can actually be something that could be very beneficial to the company. I think it's getting the senior management team on-board to actually understand what it is and how we can introduce it.

Phil

Cam showed an awareness of the importance of developing the skills within the organisation in response to Industry 4.0. He was comfortable that the pace of the organisation's adoption meant that there would be time to develop the right skills. However, he was not able to share specific development plans or the mechanisms which would support the needed development.

Cam:
the pace at which we're moving down that journey means that we can actually up-skill people or change people's capabilities and in a timely way. I don't see that being a huge issue.
Researcher:
What sort of skills do you anticipate needing more of in the future?
Cam:
I think it's more so around ... A lot of our portfolio of people are what's called surveyors or those who look at physical equipment and they perhaps don't have an appreciation or understanding of the data and analytic side. I think it would be a steady ... There'd be an up-skilling of those guys and girls to have a greater Industry 4.0 data and analytics capability and over time as that pool diminishes because we're going to be moving to more things like remote survey and all the rest of it, actually the mix of those people will change as well.

Cam

Supporting

Supporting behaviours are defined as 'showing positive regard, building cooperative relationships, and helping people cope with stressful situations' (Yukl, 2012, p. 71)

Supporting behaviours were minimally demonstrated by participants in response to Industry 4.0. Jay demonstrated the most supportive behaviour; however, he was the participant who was least engaged with Industry 4.0 adoption.

in the type of role I do it's super important that as much as anything else I am most honest and as transparent as I can be with my customer and my team.

Jay

I really enjoy the just building an organization and culture that needs to come with it. Because I get to see everyday, you know, as every new person walks on the floor plane. When you're building up the road, it's only ours. So when I started it was literally 75 empty desks, me and the core office and a handful of others, and it's now the floor plan's just buzzing.

Jay

Recognizing

Yukl defines recognizing behaviour as 'providing praise and recognition for effective performance, significant achievements, special contributions, and performance improvements' (Yukl, 2012, p. 72).

In response to Industry 4.0 adoption and utilisation, there was limited data gathered that demonstrated that the participants used recognising behaviours. Jay was the only participant who provided one example of demonstrating recognising behaviour.

We took the team out Thursday before last, to celebrate a couple of weeks of wins, and that was really fun.

Jay

Empowering

Empowering behaviours focus on leaders 'giving subordinates more autonomy and influence over decisions about the work' (Yukl, 2012, p. 72). Consultation and delegation are considered empowering procedures within this behaviour component; in a previous iteration of the behavioural taxonomy, consultation was a behaviour subcomponent of relations-based behaviour (Yukl, et al., 2002).

Mitch thought that empowerment of subordinates was a key behaviour to enable the successful adoption of Industry 4.0 technologies, to the extent that any 'top-down' change effort would fail.

It's actually a very powerful thing, because I think the mindset of senior management or the exec team, or whatever you want to call them, I think if you try and drive that philosophy from the top you'll strangle it, and it will not work. Ultimately, you really do have to let go of an awful lot of that, and you need to let groups and individuals within the organization to actually develop and try too. That is a completely different mindset.

Mitch

Mitch proposed that it would be a radically different type of leadership 'mindset' to empower the subordinates to the extent that he envisioned would be necessary.

Phil planned to consult his subordinates on how to utilise the Industry 4.0 technologies; he planned to do this as a tactic to get their support for the changes.

As in ... because also, as well, I've persuaded, I've talked to my boss about it and what benefits it can bring, but there'll be a lot of people on the shop floor who are like, "Are you trying to replace our jobs?"

Phil

Cam also demonstrated awareness of empowering subordinates to contribute to Industry 4.0 changes; he recognised that the organisation had the support of employees currently, but without action, the employees would lose engagement.

I'm aware that if we're here in three years' time still talking about some of these things without active progress people will lose interest.

Cam

Jay stated that he empowered his team, demonstrated by respecting their functional expertise and allowing them to make decisions to identify technology that improves capabilities.

As long as we can define the problem, as long as there's more brains in the room than mine, that will work out, because I've got a really bright team that I trust.

Jay

I trust, to an extent, the fact that, if engineering says, "Here's a new set, technologies capabilities or processes, that will let us do what we do better," my engineering leader in the company, I don't design aircraft, and I trust that the guy making that decision understands more about it than I do. I can get happy with that fairly quickly, I think. Like I said, it's a big business, so it goes with employing operations tools. There's teams of people that look at these things to understand, is that the right decision for the business? And as long as I'm aware of it and aligned to it, then I don't have to think too hard.

Jay

However, when Jay gave a more specific example of how he leads his team and analyses data, he shared that he personally likes to understand the data on the same level of granularity as his teams. He is aware of the importance of empowering his team but struggles to demonstrate trust unless he is personally satisfied with the data analysis. Once that trust threshold has been met, his behaviour shifts to being more relational for future reviews.

If they understand the problem, then our focus is what's on the chart, because that's all data-driven there. But if they don't solve the problem, then we have a personal problem rather than a data problem. So, I would say I take 75 percent of my reading of how things are going off of the people that bring me the issue.
Researcher:
Okay, so you rely on your team to critically analyze the data and almost be like a personal filter, before it comes to you?
Jay:

Yeah.
Researcher:
Okay.
Jay:
Yeah, and so maybe ... So I do worry that I disempower them a little bit by getting into the data myself, so I just consciously think through, how much do I want to really drill data sets that they should have drilled, when that's their job? Just because, my thought process is driven to data, so I quite like to understand the problem to the end degree before I convince myself it's been solved. But I have to constantly remind myself that that can be frustrating to the team. If the net of it is, "Oh yeah, so fine like we said," then all I've really done is waste seven minutes of your time. Understand the problem in a detail that really I could have just trusted the voices around me.

Jay

Discussion of the extent that relations-based behaviours were exhibited

Relations-based behaviours were demonstrated to a limited extent in this study, with the component behaviours developing and empowering have the most data to support their inclusion in the taxonomy in response to Industry 4.0 technologies. Supporting behaviours were demonstrated by Jay, however that was not in response to Industry 4.0 technologies.

Overall, Jay was the participant that showed the most relations-based leadership behaviours; he was also the participant who was least engaged in adoption and utilisation of Industry 4.0 technologies. The data extract below highlights the juxtaposition that he feels exists between his preferred leadership behaviour and the use of Industry 4.0 technology.

I like, between me and my team, to have gone through enough of an understanding of the data in front of us, to be able to agree with the decision that's being presented. The idea of getting that responsibility to something that's automated and trusting…I don't particularly feel comfortable with that. Although I've not gone through that experience.

Jay

This perceived conflict between relational leadership styles and the use of Industry 4.0 technologies could explain why Jay is hesitant to engage with adoption efforts.

Although the data did not show observable behaviours, the importance of relations-based behaviours in Industry 4.0 was recognised by Mitch, who provided a summary of his thoughts:

You can lose the organization and the people within it as well when you sit there and go, "What the hell are you doing? This is never going to work." That gets into the whole thing around the strategies around 4.0, about how do you actually engage a workforce, an employee base, how do you engage them and in terms of driving it forward.

Mitch

Relations based behaviour was viewed as a key component to getting subordinates to engage with the effort required to bring Industry 4.0 technologies into the organisation. In Industry 4.0 context, relational behaviours were used to build trust and knowledge share, via the behaviours developing and empowering. The impact of leadership behaviour on creating trust with followers in order to share knowledge is positively correlated in the literature (Ba Lee & Lei, 2018) (Naeem, et al., 2021). The studies used transformational leadership as their lens on leadership behaviour, hallmarks of

which include encouraging employees to develop new skills, and centring commitment to the organisation. This maps to the relations-based meta category goals and behavioural subcomponents

Ned, Cam and Phil also demonstrated limited relations-based behaviour. Phil and Ned were quite new in their role and appeared to be more focused on achieving clarity in how Industry 4.0 technologies could be used in their organisation. Their relational efforts were more aligned with the definition of 'networking' behaviours in the taxonomy, discussed in further detail below.

Cam was aware that his leadership behaviour was not relations-based towards subordinates.
Cam: I'm quite direct and goal orientated, and I understand how to get there. It takes quite a lot of effort for me to gather people round and create a team to actually achieve that. And that's probably why I'm not managing a team just now.
Researcher:
But you obviously successfully did it when you had your technology development and your startup. Is that because you had a really clear goal? So the clearer the goal, the easier it is.
Cam:
Yeah. I think that's a very valid observation. And, I mean, the company was only two or three people when it was bought. It was mostly acquired by [organisation] for the technology. And there's 20 or 40 people working with it now, within [organisation]. Which is great. But part of the reason I didn't grow the company larger was because I know it's not my strong point. I'm much better dealing with the technology and, I think, influencing than I am in building a team. I'm not very good at that at all, and it doesn't interest me.

Cam

Cam highlighted the behaviour of 'influencing' as a method that he displays to achieve the organisation's goals, as well as being a subject matter expert on technologies. Influencing is not a behaviour that is currently included in the taxonomy; wider literature defines influence as 'compelling behaviour change without threat of punishment or promise of reward [which] results largely from the respect and esteem in which one is held by others' (Baxter & Lucas, 2011, p. 49). In Cam's scenario, he is respected for his knowledge of technologies and he benefits from being held in esteem by the wider organisation as a result.

In summary, the behaviours demonstrated by participants in response to Industry 4.0 fragment when viewed through the lens of the relations-based meta-category, and the behavioural subcomponents. Empowering and developing behaviours were the most demonstrated; however, they were done with the goal of knowledge sharing within the organisation, which does not align with the taxonomic definitions. In addition, the behaviours were not directed towards subordinates, as the taxonomic definition implies. The participant who demonstrated the most relational behaviours was the participant who was least engaged with Industry 4.0 technologies, and they perceived a conflict between relational behaviours and Industry 4.0 technology adoption. In addition, Cam consciously rejected relational behaviours, but acknowledged that he benefited from being held in positive esteem by the wider organisation. In this scenario, it could be viewed that the wider organisation displayed relational behaviours towards Cam which he did not necessarily reciprocate, and instead provided knowledge. T the finding on relational behaviours appears to be a

wider theme regarding relational behaviours and knowledge creation and dispersion in organisations that the taxonomy structure does not currently support. A proposal to address this is included in the adapted taxonomy proposed in the summary of this chapter.

Change based behaviours

The third meta-category within the hierarchal taxonomy of leadership behaviours is change-based behaviours. Within this meta-category, the key goals for change based behaviours are 'to increase innovation, collective learning and adaptation to external change' (Yukl, 2012, p. 72) . These goals are supported by the specific behaviours of envisioning change, encouraging innovative thinking, risk taking and external monitoring.

Advocating Change

The component behaviour of advocating change is observable by 'explaining why change is urgently needed, observable examples include similar work unit or competitors have better performance, explaining threats and opportunities, and undesirable outcomes if they are not responded to' (Yukl, 2012, p. 73). Taking risks for change was previously a behavioural component in the 2002 version of the taxonomy, which is now included in advocating for change 'in recognition of the likely resistance to change a leader will face and the courage required to keep advocating' (Yukl, 2012, p. 73).

The participants shared how they perceived they would advocate for change involving Industry 4.0, and the level of personal risk that they would have to take to ensure it was adopted.

Yeah. Yeah. Sorry. I was going to say, yeah, exactly that. There are checks and balances. I would introduce ... I don't have sole authority to sign the purchase order. To make it happen, there's a body that ... Actually, quite interesting. We do have quite a strong ... Within the innovation team there's a kind of regular forum where new technologies and any of these investments are probably categorized and subject to investment review before they go ahead.

Cam

I have the authority to propose a new technology. In order to successfully install it I need approvals from IT. I need export control approvals. I need privacy approvals. I need a whole boatload of approvals.
Researcher: Does that inhibit you [inaudible 00:18:20] ?
Ned: Completely, but it also prevents me from making really horrible mistakes.

Ned

I don't think it would get to that point. There are checks and balances that I wouldn't spend 10 million quid and then find out it was worth nothing.

Cam

Several of the participants shared that they were empowered to advocate for change within their organisation structure. In order to be successful, their advocacy needed to include following internal approval processes which are designed to limit the risk exposure for the organisation, and as a result, the risk exposure for the individual participant. The procedures were recognised as a barrier to adoption but were viewed as a necessary mitigation measure. The participants did not display frustration or an intention to drastically change the procedures.

Jay shared how he advocates for change; his advocacy had a more relations-based component as he demonstrated empowering his team to take risk for change. However, he still had a focus on being able to quantify the risk and financial commitments, although he did not reference having to gain wider organisational buy in via a cross-functional review.

equally I think it's helpful if we are, I hate the word courageous because it's a little bit corny and a little bit cheesy, but I think given the type of stuff we do its helpful if we are just, if we just lean forward in taking risks with some of the technologies that we develop.
None of it's easy, but that's just true to say. So, if we're not willing to take tactical and strategic and technical risks than we never really advance it, so I think that's a big part of again if I can reflect into my team, hey listen, risk taking is okay as long as we can quantify what it means and we calculated in where that exposes us from a technical and a financial perspective. Then that's a good leadership behaviour for me to demonstrate for the team so they go do all the things they need to do for us to be successful

Jay

Envisioning Change

Envisioning change is characterized by 'articulating a clear, appealing vision of what can be attained by the work unit or organisation' (Yukl, 2012, p. 73).

Ned showed strong conviction when envisioning his role in adopting Industry 4.0 technologies for the organisation; he used this conviction to demonstrate to his manager what skills Ned would bring to the change effort, despite not having any technology-based skills.

But what I will do for you [Ned's manager] is figure out what use cases we can meet through the application of this technology, figure out the costs and benefits of doing so, and then implement it in a programmatic way.

Ned

As part of envisioning the changes that Industry 4.0 could bring, the participants discussed how they are finding and choosing valuable technologies for their organisations. The word 'roadmap' was frequently used; there appeared to be an implicit understanding that the technologies and the organisation's maturity of use would need to be iterative. No participant viewed the adoption of Industry 4.0 as a discrete task.

Some participants had the goal of fully integrating the technologies into one system and wanted to identify technologies that would have that capability. They highlighted the importance of knowing the value these technologies would bring up front.

the biggest thing is when I do that business case I want to map it out, almost like a roadmap, and thinking about the whole proj-, where we want to get to, final destination and having it all ... So, if you're introducing that technology you want all systems eventually that can talk to each other, so it's having that idea of where you want to get to

Phil

There was a shared concern around correctly scoping the technology that would bring value to the organisation.

I think the pursuit of technology and technology that provide solutions to customers is a never-ending quest.

Mitch

Mitch perceived the 'never ending quest' as driven by solutions to customer satisfaction; Ned added the pace of technology development itself as a nuance to this viewpoint.

I don't think I could find a single person in this organization who is happy with the technology that they have. I'm being a bit silly for a moment. I don't think I'd ever find out that how you could give him 10 billion to go spend and still want more because, per our previous conversation about the importance of technology by the time something's bought, installed and operational, the next shiny thing is coming around the corner.

Ned

As mitigation against this, Ned focused on the analysis of the potential outcomes of the technology adoption at an early stage of the change effort.

There's a million and one thing you can do, but in determining what you should do, you need to have an understanding of the costs and benefits of every individual project.

Ned

Cam summed up the risk with mismanaging the scope of identification and implementation succinctly.

That's the risk is we're continuing to look at things that are interesting rather than landing the really important things and then going back to kind of horizon scanning.

Cam

To address this concern, consideration of as many factors as possible at an early stage was important. Phil viewed this as a requirement to get the wider organisation bought in to the changes and for him to feel confident with his implementation plan. He also alluded to the challenges he was facing getting senior management support, and he foresaw that having a comprehensive, visual plan would become a strong communication tool.

To actually visually demonstrate that I think would be a really good selling point and get the senior management team on board. It would help with the business case massively. But again, the business case is, I want to include as many different factors as possible but try and get as accurate data as possible, which would also help with being confident and ensuring that what I'm proposing is going to work.

Phil

Jay acknowledged that he had not envisioned a future using Industry 4.0 technologies. When asked to as part of the interview, his thoughts went to a relational based perspective revolving around the level of trust. He stated that he didn't have the level of trust needed to envision the changes, in the technologies or in his team.

Yeah, not something I've given any thought to, here in the level of tactical problem that we've got. This is a great question. So, it requires the levels of trust, I don't know that I have myself, in technology. I don't know that I've got in my first line leaders. If I envision a future that's 50 years away, where we come in and there's a whole bunch of data around us that just does things for us, that makes decisions for us-

Jay

Encouraging innovation

Sometimes referred to as intellectual stimulation, encouraging innovation involves 'challenging people to question their assumptions about the work and to consider better ways to do it' (Yukl, 2012, p. 73) Observable behaviours include the 'creation of psychologically safe environments for team members, providing opportunities and resources to support novel ideas and championing innovative proposals' (Yukl, 2012, p. 73).

Phil was currently challenging his management team about the assumptions made in the organisation and proposing new ways of working. His tactic to achieve this was to create a small pilot project and provide a full business case for full adoption of Industry 4.0 technologies.

Then I think it would get easier because [organisation] is quite forward-thinking, but they have to ... the question is, "What cost savings does it give me? What benefit does it give me?" And if you've proven it once then it'll get a lot easier for approval after

Phil

Mitch encouraged innovation by challenging innovative proposals to consider better ways to 'add value. This protected resources and opportunities for more viable, impactful projects.

At the same time, trying to make sure that things aren't developed that don't add value and don't become pinned projects, and basically are sidelined and killed off, because again, there's an awful lot of that. A lot of people are incredibly enthusiastic about developing technology. But, is there any use? It's nice and it's interesting

Mitch

Jay displayed a negative form of encouraging innovation; his perception was that his role did not require him to be involved in determining the right technology for adoption.

Essentially, do I drive that function, or do I drive my business? My job is to drive my business. And if the function has decided for itself that here's a thing that's useful to us, I'm going to want to understand that, in of detail, that within my business area, that we don't get its deployment wrong. But it isn't my job to influence the decision making around that particular thing.

Jay

Facilitating collective learning

This behaviour component of change-based behaviour focuses on the 'improvement of current strategies and work methods (exploitation) or discovery of new ones (exploration)' (Yukl, 2012, p. 74). It is observable when a leader supports 'activities to acquire new knowledge, from internal and

external sources, influences how new knowledge or a new technology is diffused and applied by explaining why it is important, guides the process of learning how to use it, and encourages the use of knowledge sharing programs' (Yukl, 2012, p. 74).

Phil arranged educational sessions for the senior management team, creating opportunities for them to expand their knowledge. He arranged these for lunchtimes, to make attendance easier and to make the learning environment less formal. He also invited the managers to attend informational sessions with potential Industry 4.0 vendors. However, the education and engagement of senior management had limited success for Phil. He stated that educational sessions had been accepted and then deprioritised at short notice.

I think a lot of people, some of the meeting invites, I've had people, have invited people to sort of ... "Oh yeah, I'll come, I'll come" and then don't turn up. Or get ... not on purpose, but if they've got an important meeting that's been reorganized, so they've gone to that instead. So it's that. I think it's still a challenge to help make people think, to get them up to, to understand how important it is.

Phil

This example highlights how a leader can facilitate collective learning, but without engagement from the wider workforce, the behaviour by itself is not strong enough to meet its objective.

Discussion of the extent that change based behaviours were exhibited

Change based behaviours were demonstrated by all participants in the study. The participants who were actively engaged with Industry 4.0 technologies understood that adoption and utilisation would mean change and innovation for their organisations; therefore, the strong demonstration of change-based behaviours is not unexpected as the overall goal for this behavioural meta category is 'major innovative improvements (in processes, products, or services), and adaption to external changes' (Yukl, 2012, p. 73).

The change-based behaviours demonstrated by participants were directed at their peers or senior management, rather than subordinates. The objectives of the behaviours were to reduce resistance and achieve support for their proposals regarding Industry 4.0. The use of change based behaviours directed at peers or senior management is a finding that is not currently reflected in the behavioural objectives that Yukl identified. The current objective reflects the dyadic relationship between leader and subordinate, as a result of the methodology used in the studies that underpinned the formation of the taxonomy. The impact of the dyadic view on taxonomy formulation is discussed in detail in the later section 'Beyond Dyadic Behaviours between Leader and Subordinate'. An update to the objectives of change based behaviour to reflect their wider scope is proposed in the summary at the end of this chapter.

The participants focused on the importance of cross functional support; several participants were using existing procedures to give their proposals visibility and gain organisation evaluation. This had the effect of reducing the level of risk that the participants needed to take to advocate for change.

Externally focused behaviours

The goal for the externally focused meta-category is to 'provide relevant information about outside events, get necessary resources and assistance, and promote the reputation and interests of the work unit' (Yukl, 2012, p. 74). The behavioural subcomponents are networking, external monitoring, and representing.

Networking

The aim of networking behaviour is 'building and maintain favourable relationships with peers, superiors, and outsiders who can provide information, resources and political support. It includes relationship building tactics such as finding common interests' (Yukl, 2012, p. 75).

The participants demonstrated networking behaviour inside and outside their organisation. For Ned, the internal networking was very important as there was no leadership role that consolidated Industry 4.0 efforts across functions.

I've identified other folks that have been tasked with similar things elsewhere in the organization. We have a very small future tech department. We have a very small digital manufacturing department and there are folks just like me out there thinking in a very similar way that I am, and we're not formally connected at all, but we found each other. We're sharing knowledge, we're sharing experience, we're sharing work arounds where we found them in order to advance these agendas.

But yes, certainly IoT. We don't [use sic] Industry 4.0 very much here. I don't know why. Maybe I haven't found those people yet, I haven't found that tribe.

Ned

Phil also demonstrated networking behaviour, by seeking out external events to connect with other people on Industry 4.0 topics.

But then just listened to a lot of people, like yourself, at the expos, just talking about all the different sort of, how you can use that and how you can, what industry 4.0 means

Phil

However, Phil's attempt to network internally were challenged. Phil had been recruited as part of a succession plan; however, his predecessor was remaining in the role for longer than expected, preventing Phil from building networks. He felt that this led to his efforts being viewed as a side-line, pet project rather than embraced as a core strategy.

Researcher: Do you find that your predecessor still being here impacts your kind of level of influence in trying to make these changes?

Phil: Yes. Yeah. But it's good working for, learning from him, because he's got a hell of a lot of knowledge and I've still got a lot to learn from him. But yes, there is that sort of ... because he's still the manager, he then gets invited to all the meetings that maybe, at times, I should be at. Especially ... but again, people don't understand the digitization yet, or fully, they just know, oh, [Phil]'s working on that. They don't know that project needs working on. If you actually introduce the digitization now at the early stage, you'd make things a hell of a lot easier for you in the future.

Phil

External Monitoring

Yukl defines external monitoring as 'analyzing information about events, trends, and changes in the external environment to identify threats and opportunities for the organizational unit', also known as 'environmental scanning' (Yukl, 2012, p. 75). Within the category of external monitoring, information sources such as industry and government reports, attendance at conferences and trade meetings and discussions with suppliers and customers were identified. Data gathered in this research study showed that participants engaged in this behaviour with these types of information sources. This behaviour was a core element of developing their response to Industry 4.0 technologies, as the participants first sought to understand and learn more.

Most of the participants described the actions they took to build their knowledge on what they understood to be Industry 4.0., and the actions that they took to find the information. However, Jay did not specifically seek out knowledge on Industry 4.0.

I started doing research and then going to a lot of the expos. I've been to the Manufacturing Technology Center in Coventry, the Advanced Manufacturing Research Center in Sheffield. I looked around the 2050 factory there, got a good idea of what technology is out there at the minute. But then just listened to a lot of people, like yourself, at the expos, just talking about all the different sort of, how you can use that and how you can, what industry 4.0 means

Phil

A mixture, I think. Media, mainstream media ... trade press, colleagues.

Ned

Probably through oil and gas industry publications on the web. And yeah, I would say that's how I became aware of it

Cam

I've been a regular participant in the World Economic Forum, and obviously, I happen to be there when that [industry 4.0] was launched

Mitch

The participants focused their external monitoring on information from institutions that they viewed as reputable.

Representing

'Represent their team or organisation in transactions with superiors, peers and outsiders such as clients and suppliers. Observable behaviours include lobbying for resources and assistance, promoting and defending the reputation of the team or organisation, negotiating agreements, and coordinating related activities' (Yukl, 2012, p. 75).

Cam represented the organisation on a regular basis, by giving webinars promoting the technology of the organisation. He viewed this behaviour as part of his role responsibility and did not see it as directly relating to Industry 4.0.

I probably give a webinar every two or there months as well just on various bits and pieces…Why do I do them? Because part of my job is involved in promoting technology and promoting [organisation]. That's probably why I do them. Because it's part of my job. Who do I give them to? Probably, I've got no idea. They're maybe a couple of hundred to a thousand people at a time. They're all organized by the marketing teams so I find it quite hard because you're speaking in a room like this to a phone with zero feedback. It's not like presenting a paper. You've got no queues at all to understand how the audience are receiving it. So that can be challenging. And what do I do it on? Pretty much any part of my job.

Cam

Jay also demonstrated representing behaviours that were not connected to Industry 4.0 technologies; his representing efforts were focused on the political environment external to the organisation.

So I spend a good proportion of my time worrying about the external influences to our business, because while they're the stakeholders, they're not the kind of thing that you can influence all of the time. Their impact on business is massive. So we have to keep working hard to ensure that the voice of [organisation] is heard and our reputation isn't unduly sullied

Jay

Discussion of the extent that externally focused behaviours were exhibited

As part of their external monitoring activities, participants attended trade and technology conferences and events. At these events, they met with suppliers of Industry 4.0 technologies. The literature confirms these actions as hallmarks of external monitoring behaviour. The participants shared that they believed these actions to be important to their identification and implementation of Industry 4.0 technologies, due to a lack of knowledge and understanding within their own organisation. Ginter and Duncan found that higher levels of external monitoring is needed when an organisation is 'highly dependent on outsiders (e.g. clients, customers, suppliers, subcontractors, joint venture partners), the environment is rapidly changing, or the organisation faces severe competition or serious threats from outside enemies' (Ginter & Duncan, 1990). The behaviour of the participants in this study supports this position; the participants recognised the lack of knowledge within the organisation as well as the rapid pace of technology affecting their operating environment and responded by seeking external information sources.

Jay did not show externally focused behaviours relating to Industry 4.0, as he did not recognise the impact that the technology might have on his industry.

Yet you've got me thinking about, is it going to be in 10 years time, and therefore do we need to be in front of something today, just to either not get overtaken or consumed by it? Maybe that needs some thought. But it doesn't, if I'm honest, it doesn't occupy thinking time today, because relative to the problems that we have to solve, it is not an issue for us today.

Jay

However, his industry is highly dependent on government funded joint ventures, and he demonstrated strong representing behaviours directed towards that area. This further supports the position of Ginter and Duncan (Ginter & Duncan, 1990).

Networking behaviours were strongly demonstrated by Cam and Phil; both participants had similar context to their behaviour with an absence of senior leadership support and coordination. Ned used internal networking to find other functions with similar goals, to try and coordinate efforts for maximum effect. Phil focused his efforts on external networking to be able to bring knowledge back into his organisation, and to gain the support of his management team.

Summary of the evaluation of to what extent previously identified externally focused leadership behaviours are present in strategic leader responses to Industry 4.0

At the meta category level, the participants strongly demonstrated externally focused behaviours and change based behaviours. To a slightly lesser extent, task based behaviours were also demonstrated and relational behaviours were demonstrated the least. The behaviors that were most demonstrated were aimed at bringing more knowledge of Industry 4.0 into the organisation, and to gain wider support at the strategic level for the technology adoption. Therefore, some behaviours were demonstrated, but with different objectives to the ones identified in Yukl's taxonomy. The table below highlights the proposed changes to the behavioural aim. Detailed discussion of the implications is provided in the cross analysis of objectives section.

Behavioural Subcomponent	**Original Subcomponent Definition and Aim** (Yukl, 2012)	**Subcomponent Definition and Aim, updated with the findings from deductive analysis from this study**
Clarifying	'ensure that people understand what to do, how to do it, and the expected results' (Yukl, 2012, p. 70)	'ensure that the plan will meet group or organisational objectives and that people understand what to do, how to do it, and the expected results'
Developing	'increase the skills and confidence of work-unit members and to facilitate their career advancement' (Yukl, 2012, p. 71)	'increase the competencies of all members of the organisation and support the development of roles and responsibilities that match the needs of the organisation'

Identify if any uncategorised behaviours are being exhibited in strategic leader responses to Industry 4.0

In order to support integration into the hierarchal taxonomy, and the wider body of knowledge, the data was evaluated for uncategorised behaviours using the criteria that Yukl originally defined for the first edition of the taxonomy. The criteria to select behavioural components are

1. 'Each behaviour must be directly observable
2. Each behaviour must be potentially applicable to all leaders in organisations
3. Each behaviour must have primary relevance for one metacategory, even though it could have secondary relevance for the other metacategories

4. Each behaviour must be grounded in prior theory and research on effective leadership' (Yukl, et al., 2002, p. 17)

By taking this approach, this research study is following the recommended approach that 'researchers should examine results for the specific behaviours as well as the metacategories in the same study' (Yukl, et al., 2002, p. 30).

Bridging External Monitoring and Envisioning Change

Yukl's taxonomy identifies external monitoring and visioning as categories within the meta category of change orientated leadership behaviour. However, interpreting and analysing the information gathered via external monitoring and integrating the findings into a vision for followers is not categorised as a separate behaviour, despite some change management studies showing its importance in change management (Kotter, 1996) (Nadler, et al., 1995). The literature review previously identified that in comparison to Fleischman's taxonomy, there is an omission of a behavioural component relating to 'organizing and evaluating information' (Fleishman, et al., 1991).

Within this study, a key behaviour demonstrated by participants related to how they validated the information from sources outside of their organisation. They viewed information from suppliers with less trust, in particular the supplier's claims of experience with technologies.

some companies are like, "We've been around for 30 years." I'm like, "How?" This technology hasn't been be around for 30 years. Anyway, that's my own pet peeve.

Ned

I think there is a lot of jargon, I think there is ... a lot of companies use it as a marketing tool as well, from a lot of things that I've seen.

So it really is a challenge and an opportunity to get people to understand what it is and remove all of the jargon and all the marketing from all the different companies to say, "This is what it is, this is the benefit it can bring and help me do it."

Phil

This critical analysis of the reliability of data found via external monitoring behaviours has not been categorised within the taxonomy. It appears that the behaviour is a critical bridging step for the leaders as they begin to interpret, analyse, and integrate this knowledge into operational and strategic activities. Reviewing this behaviour against the primary objectives of the metacategory of change-based behaviours 'to increase innovation, collective learning and adaptation to external change' (Yukl, 2012, p. 72), it could be proposed that critical analysis of external knowledge and information would be a specific component behaviour that contributes to adaptation to external changes.

Mission Matching: Making aligned, values driven decisions

The organisation that Cam worked for was a private company, that was founded on not-for-profit principles. Cam described the influence of these principles on decision making behaviour.

Cam: What was I saying? I think if we think about innovation and the range of exploratory type work that's happens, there's a high degree of tolerance of things that perhaps deliver less or perhaps

negligible sort of benefit. So, there's quite a high degree of tolerance for that. Which is good. It's almost blue skies research support, by another name.
Researcher: Okay. That's quite good. So the benefit isn't defined as how much cash return investment are we getting here.
Cam: Well, I think, it's not always like that. It's far less. There's a higher degree of tolerance for that than I've seen anywhere else.

Matching the written mission of the organisation with actions taken is not a behaviour that has been identified in the taxonomy; however, it could meet the criteria for a behavioural component.

1. *Each behaviour must be directly observable*
   In this instance, the behaviour was observable by the organisations mission being a criterion within the decision-making regarding technologies. Other observable examples could be the inclusion of values within a performance management and evaluation system, and other organisation policies.
2. *Each behaviour must be potentially applicable to all leaders in organisations*
   The organisations mission is not specific to one function or role.
3. *Each behaviour must have primary relevance for one metacategory, even though it could have secondary relevance for the other metacategories.*
   This behaviour could have specific relevance for relations-based behaviours, as it supports the goal of building 'strong commitment to the unit and its mission'.
4. *Each behaviour must be grounded in prior theory and research on effective leadership*
   Demonstrating transparent decision-making processes that are not based on a leader's self-interest and modelling that behaviour for subordinates is an identified component of authentic leadership theory (Avolio & Gardner, 2005). Although authentic leadership theory has been criticised for having a weak theoretical basis and inappropriately broad construct (Alvesson & Einola, 2021), the specific components identified are additionally supported by social exchange theory, through which leader effectiveness is enhanced by creating positive social exchanges with followers, resulting in high levels of trust (Ilies, et al., 2005).

Beyond Dyadic Behaviours between Leader and Subordinate

Leadership behaviour has benefitted from the attention of researchers over the previous seventy years; Yukl states that the hierarchal taxonomy of behaviours was developed with the aim to integrate the findings. The meta categories of task and relations-based behaviours integrate findings from some of the earliest studies, and it is important to note that the framing of leadership in these studies focused on the interaction between the leader and their subordinates. This lens restricts the available data to behaviours that the subordinates observe and interpret, and therefore the conclusions that can be drawn from these studies are limited to the dyadic interactions between the leader and subordinate.

The findings in this study show that the participants did demonstrate behaviours that can be classified as task based and relational; in particular, the behaviours that participants demonstrated were to seek and define clarity, rather than to provide clarity as implied in the behavioural definition

‘ensure that people understand what to do, how to do it, and the expected results.’ The findings in this study suggest that the behavioural definition could be expanded to include the behaviours that leaders undertake prior to directing clarification behaviours towards their subordinates.

The meta category of relations-based behaviour is also based on early studies that had a dyadic framework. The specific behavioural components do not specify that they are directed towards subordinates, although the criteria for each behavioural component strongly implies that the leader would be in a higher level of positional or skills-based power when demonstrating these behaviours. The participants in this study demonstrated relational behaviour such as developing and supporting towards a wide range of stakeholders, such as their senior managers and their customers, with whom they have a limited amount of power.

The defined goal of relations-based behaviour is a ‘strong commitment to the unit and its mission, and a high level of mutual trust and cooperation among members.’ When the participants demonstrated developing and supporting behaviours towards their senior management and customers, the participants’ goals did not fully align with this. When Phil demonstrated developing behaviours towards his management team, his objective was to increase their knowledge and confidence so that they would support his vision for change. It could be argued that this behaviour could be categorised as facilitating collective learning, but it does not fully meet the criteria for that behavioural component either as it did not directly lead to the ‘improvement of current strategies and work methods (exploitation) or discovery of new ones (exploration).’ Therefore, the behaviour demonstrated by Phil best meets the criteria for developing behaviours, but the goal for the relations based meta category could be expanded to reflect that relations-based behaviours can have a wider objective than the goal currently defined.

The supporting behaviour demonstrated by Jay was partially directed towards his customer, in that he highlighted the important role that transparency plays in his relationship with them. He perceived that this made him more effective in negotiations with the customer and led to ‘win-win’ situations. This met the component definition by ‘building cooperative relationships’ but again did not fully align with the meta category goal. This example further supports the proposal that the definition of the relations-based meta category should be further expanded.

Evaluate the behaviour demonstrated by strategic leaders in response to Industry 4.0 in comparison to the enablers and inhibitors identified in the literature to date

Definition of Industry 4.0

One of the most consistently discussed features of Industry 4.0 was the lack of clear definition for the concept, for both practitioners and academics. Previous studies had identified that ‘’Companies lack a clear idea of Industry 4.0 resulting in uncertainty regarding benefits and outcomes’’ (Schumacher, et al., 2016, p. 163). The participants responses in the study demonstrated ambiguous understanding of the definition of Industry 4.0, as well as relevant sub-technologies.

I still don't understand the distinction between AI and machine learning. And it's funny, I don't hear big data as much as I used to. I think we like automation, we like IoT. We like AI and machine learning in a big way. We don't use big data very much, although we talk about data lakes a lot. But yes, certainly IoT. We don't [use sic] Industry 4.0 very much here. I don't know why.

Ned

Jay: Yeah, so let's talk about the Industry 4.0 okay. What do you specifically mean?
Researcher: So the artificial intelligence, big data, internet of things, that's all Industry 4.0 and do any of those ring a bell?
Jay: I think at least one of them.
Researcher: Okay, good. We'll come onto that.
Jay: Big and data, I think resonated.

Jay

It's what people are terming as the next industrial revolution, using emerging technology, such as artificial intelligence, machine learning, the industrial internet of things. And the big thing behind it is collecting a lot of data to then use that data to make decisions.

Phil

Just for my understanding as much as anything, can you explain what you mean by industry 4.0? The reason I ask is there can be data collected for ... And I get most of my familiarity is with industrial plants ... That is collected for equipment and plant that isn't sensor fed. You know, there are various definitions of Industry 4.0 that sometimes include and exclude that, so that's the reason I ask for it.

Cam

It's really bringing together a whole, or trying to describe a whole bunch of things that are going on, and bringing it all into convenient or a digestible way of trying to understand a lot of things that have been going on. It didn't all happen at one point in time. There's a whole bunch of things that have been going on, and there's a lot of things that have been put under that umbrella… there's also sorts of definitions of all sorts of things, and they're all being lumped into this, under the same thing, whether it's IoT, or whether it's new development materials, printing, digital.

Mitch

In their responses to defining Industry 4.0, the participants showed a wide range of descriptions that centred on the use of information that the organisation gathered. However, they diverged on how data is captured by referencing different types of technologies. They also diverged on their perspectives of appropriate data sources and capturing techniques for their organisations.

The data gathered in this study support the position in the wider literature that there is no widely accepted definition available for Industry 4.0. In comparison with the behaviour's demonstrated by the participants, it was observed that the clarifying behaviours were demonstrated with great enthusiasm but little depth. The lack of clarity on Industry 4.0 is reflected in the leader's behaviour's as they sought to scope and evaluate the adoption of the technologies. This also supports the position in the literature that the lack of definition can be deemed a factor that impedes adoption (Schumacher, et al., 2016).

The definition adopted for the literature review was "Industry 4.0 is the sum of all disruptive innovations derived and implemented in a value chain to address trends in digitalization, autonomy, transparency, mobility, modularization, networking and socialization of products and processes." (Pfohl, et al., 2015). In comparison with the results from the study participants, Pfohl et al's definition supports the view that Industry 4.0 is the sum of a range of technologies but lacks enough focus on the role that data plays. Consequently, an updated definition could be: Industry 4.0 is the sum of all disruptive innovations that derive value from the capture and networking of data to support organisational objectives.

Evolving Nature of Core Technologies

All the participants spoke about being overwhelmed by the velocity and volume of the technology to be assessed for adoption by the organisation, which the literature recognises as hallmarks of Industry 4.0 (Schwab, 2017) (Kohnová, 2018). However, the participants tended to frame this experience in a positive light, seeing the multiple technologies as multiple opportunities. There was a focus on ensuring that the idealistic vision does not get in the way of executing the business priorities in the short and medium term. This is supported in the literature; the view that matching the right technology at the right time as an enabling factor for successful adoption (Giustiniano, 2018).

What makes you think I don't want to? It's just not a problem I have to go and solve today. This is ... Necessity is the mother of invention. This is about, what do I need to do today to deliver the things that I've committed to the business?

Jay

I think for a business, it's a bit like being let loose in a sweet shop, I think. You really need to go and pick the things you want, pick the things that are really going to make a difference to your business. I think, too many people and companies are actually completely fixated with the blue sky one, and they get completely lost in what they're trying to do in five years' time, or what they think is possible in five years' time, as opposed to step by step pick of action. They're looking at the buzzwords, all this stuff that could be done as opposed to saying actually, "Look, what could we implement that's actually going to improve our core business?"

Mitch

Additionally, once a technology was installed, processing the data that was now available was a source of concern for some participants.

But as a community, and the customer, we have not got our arms around how we're going to use that data. The aircraft will suck up multi terabytes worth of data when it's flying, and we haven't, how do we analyze that, in a meaningful way, to go in for tomorrow's issues. That's largely because the technology is new, look at the data, look how ... that's not useful, that's somewhat useful, that's, holy shit, that's really interesting. We'll just have to go through that learning together about, the next generation of how do we take data off an aircraft and worry about what that means to how we fly the aircraft.

Jay

Despite the challenges identifying and implementing Industry 4.0 technologies, the participants could envision organisations with the technology fully embedded, demonstrating the envisioning change behavioural subcomponents of the hierarchal taxonomy (Yukl, 2012). They discussed their views on how managing an organisation would change.

One area of discussion was the increased focus on cyber security. There were some expressions of cynicism about how real the threat would be, and the participants did not seem unduly concerned

about the cyber security requirements or potential ramifications of a breach. This contradicts the available literature, which posits that cybersecurity concerns are a management challenge that inhibit the adoption of Industry 4.0 technologies (Godina & Matias, 2019) (Karadayi-Usta, 2018) (Giustiniano, 2018).

On the one hand, it's hugely important around managing the data and security, and the data. On the other hand, it is a scary place that is consultants trying to scare you into buying all sorts of stuff, and the right place is somewhere in the middle of all of that. I think it also depends on the business that you've got. If you're heavily, heavily R&D then it's all about protecting that. If you've got lots of external customers or you're dealing with the public, the right data protection, and around all of that.

Mitch

Managing Duality: Strategic Responses as Exploration or Exploitation

The literature on Industry 4.0 proposed that Industry 4.0 'represents both innovation (exploration) and efficiency (exploitation)' (Halse & Jæger, 2019, p. 136) (Giustiniano, 2018). The researchers speculated that resolving this duality may be a challenge for organisational leaders. The literature suggests that open collaboration and an ambidextrous approach to strategy may assist (Kohnová, 2018) (Karadayi-Usta, 2018). The data collected in the study showed the presence of exploration and exploitation strategies; within the description of exploratory and exploitative strategies, there were descriptions of behaviours from the hierarchal behavioural taxonomy. In addition, Yukl's goal facilitating collective learning also refers to exploratory and exploitative approaches: the 'improvement of current strategies and work methods (exploitation) or discovery of new ones (exploration)' (Yukl, 2012, p. 74). As a result, the literature on innovation ambidextrous strategies can be connected to the leadership behaviour of facilitating collective learning.

Exploration Strategies

Ned highlighted that the goal was to find new technology, aligning with the view of an exploration strategy.

we need to find technology today, which is going to keep this business in business in that timeframe.

Ned

He was able to give an example of how the organisation is supporting the exploration-based approach in its current operations; when the network was upgraded, additional capacity was created for an unknown future technology. By demonstrating strong planning behaviours, Ned is creating a situation that supports an exploratory approach.

leave a load of spare capacity in that PoE network, so when we've got our head straight on what we really want to do, we'll be able to go back and put that in.

Ned

Cam described external monitoring behaviours and encouraging innovation in support of an exploratory strategy.

they've got this innovation practice which is intended to look at horizon-scanning of new technology and, in fairness, there's a fair bit of activity around machine learning and other types of those sorts of projects. And there's a kind of fairly loose plan to bring them together into something integrated

we think about innovation and the range of exploratory type work that's happens, there's a high degree of tolerance of things that perhaps deliver less or perhaps negligible sort of benefit.

Cam

Mitch highlighted how having an exploratory strategy could expand beyond specific Industry 4.0 technologies to other areas of innovation.

Mitch: …people who are looking to apply the latest technology are more open to looking at materials as well. There might be a mix of all of that, but there are things.

Mitch

Exploitation Strategies

Several participants discussed using Industry 4.0 technologies to extract more value from existing assets. This aligns with the goal of an exploitation strategy. While the participants advocated for an exploitation-based strategy using Industry 4.0 technologies, the assets that were exploited and how that increased value varied. The exploitation strategy could be divided into three sub themes related to the source of increased value. These three sub themes are increased productivity, increased quality, and improved risk management. These areas align with those identified in the literature (Karadayi-Usta, 2018) (Sanghavi, et al., 2019).

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Increased Productivity

The participants varied in how specific they were when they identified the opportunity to increase productivity by using Industry 4.0 technologies. At the most generic level, participants spoke about speed of work completed and efficiencies within existing processes.

If you look at the opportunity, it's about faster, it's about more certainty, it's about improved response because of data. It's like life on steroids, right? It's doing everything that you could possibly want to do.

Ned

it's true that the type of technology that we develop, it is in the future, going to require us to be more efficient and effective, and decision making speed will drive us in that particular direction.

Jay

Collect data and you can improve your, reduce your process time, your lead time and then predictive maintenance, all that sort of, many benefits.

Phil

However, there were some instances of specific scenarios that the participants were able to share. These instances were hypothetical; no participant was able to give an example of increased productivity that had already been achieved.

It might be a vehicle for taking a percentage cost base out in the future. It might be a vehicle for improving the speed of decision making

Jay

it would remove one man per shift stood on the production line doing that check where a robot would come in and do that.

Phil

The theory being that if you've got a fully sensored installation with truly tuned diagnostics and you understand everything then you can put your people where it's really important. It definitely improves ... The theory is it definitely improves productivity because you're not focusing on the equipment or activities and don't need it.

Cam

I think that there needs to be an improvement around the alignment through the projects, where designs are really complete and materials and equipment are really complete. Then, the individuals where you've got a large manual interface, basically the manual interface needs to have a definitive plan, a completed design, the materials on hand, and everything there ready to do the work, and that's where productivity will actually increase.

Mitch

Ultimately, for clever solutions where you can still actually earn as much on fees, but actually reduce the cost for the customer.

Mitch

Phil, Cam and Mitch spoke of the increase in productivity that would be achieved through more efficient resource management. Resources were materials and people, and a common theme was being able to combine the two types of resource in an efficient manner.

Increased Quality

Increased quality was also identified as an opportunity that Industry 4.0 technology could bring.

Increased quality was described as decreased waste in processes and as improved customer service.

We can save a lot, we can potentially win a hell of a lot more work if we can use it and get it right. And improve our quality, being on the quality side of things, the potential to have that improvement.

Phil

Not so much because we've actually got equipment that's sensored up but having access to data from the broader Industry 4.0 would help us with our future plans and also help us service customers better.

Cam

When I take over from the quality assurance role will just give myself a hell of a lot more confidence, but you're not just relying on humans, because humans do make errors, but then also you've got that we don't 100% inspect this. So to have that 100% inspection as well

Phil

if there are quality, right first time, wastage improvements available to us from 4.0 then we need those now, not tomorrow really.

Ned

all that data that's collected, or information that's collected, using that... collecting it as efficiently as possible and then using that data to bring some, I guess, insights to both customers and LR.

Cam

In Cam's definition of Industry 4.0, he had focused on the use of sensors on equipment. However, when discussing the opportunity for using data, Cam highlighted that valuable data can be created without the use of sensors. He referred to the technology that he had developed to analyse non-

sensor data and stated that it was the value of that analysis to that could create quality customer service.

It's not sensor data, but there's an awful lot of value in that data and that's what the technology that we developed prior to becoming acquired by [organisation]'s works. So there are data sources that exist that allow you to do an awful lot of analysis and understand the equipment condition that doesn't rely on having a sensor feed….using that data does help you understand an awful lot about how your technology's working and how the customer's working and therefore help inform the future roadmap for technology development

Cam

Jay highlighted that their organisation already collects data from customer assets as a proactive customer service.

we suck data off the aircraft as it's coming in to land. And that wasn't in response to a problem, that's because that lets us solve a customer issue.

Jay

Lower Risk

To a lesser extent, the participants also discussed the opportunity to lower organisational risk by identifying risks more easily and at an early stage, where they thought it would be cheaper to mitigate.

being able to identify flaws or things that needed maintained right upfront would start better than coming into a major issue, nevermind the risk and the liability if it was really bad. But, actually being able to do that and intervene quite quickly, it's just very, very cost effective.

Mitch

However, there was also a note of caution in their discussion of risk mitigation. Cam spoke about the difficulties of quantifying the value of risk mitigation.

I think also you're kind of proving a negative, aren't you? To some degree, you're saying that by the adoption of industry for technology you won't see this thing that's happened. In instances where you've applied industry you can't demonstrate ... It's hard to demonstrate that things would have been worse if you hadn't done it.

Cam

An exploitation strategy aligns with the goal of the task-based metacategory ‘ensure that people, equipment, and other resources are used in an efficient way to accomplish the mission of a group or organisation’ (Yukl, 2012, p. 69).

Calculating Return on Investment

Calculating the return on investment of the technologies was a wide-ranging topic with participants; defining the costs included in the investment calculation was a subject of concern with participants trending towards including as many data points as possible, over the life of the technology. The literature had identified the lack of suitable investment model for Industry 4.0; the data in this study supports this view (Lee & Lee, 2015).

There are lots of equipment there that even though it’s cheap to put on sensors, it’s simply not worth it because the cost of sensoring something up isn’t just the cost of a sensor. The life cycle cost, you’ve got to put on the sensor and then at some point in time you’ll probably have to replace it. You’ve got

to maintain the cabling. Although, you've got artificial intelligence it's not free. The operational cost isn't free.

Cam

A starting point proposed was to understand the historical investment in maintenance, and to track the differences once the technology was implemented.

You've always got to work on your historical data. You take the historical data, you figure out how much you've spent on maintenance, and then you need a bit more data again utilizing this, to then take that and think about the difference between the two. But actually, just letting things run, it's like anything.

Mitch

Additionally, selecting the right level of granularity to include in the business case was a factor that the participants considered. This was particularly important to the participants who were at the initial stages of implementing Industry 4.0 technologies.

if there's a project in five years' time, that's going to cost half a million and you want the thing that you're introducing now for 10 grand to be able to talk to that half a million, £1 million piece of equipment…but again, the business case is, I want to include as many different factors as possible but try and get as accurate data as possible, which would also help with being confident and ensuring that what I'm proposing is going to work.

For the participants with the responsibility for calculating the business case, there were some unique challenges. One of which was the existing financial model of the business being incompatible with the benefit of the technology.

that's where actually the business model stuff really, really comes into it, because you've got an awful lot of these things around materials, or ways of working, or implementation, or more efficient ways of doing stuff that can be completely thrown out of the window if you've got a business model, but it's not geared towards life of asset. If it's purely geared towards topics, you won't utilize any of these.

Mitch

The scope of the implementation was also challenging to calculate the return on investment on. Accounting for the scalability of the technology was challenging, as it could often be scaled outside the area of responsibility of the project or budget holder.

if it really easily scalable, then it's going to be part of the, here's the benefit from it. So yes, we must be able to say, that particularly, if it's not just local to my business, here's an enterprise level gain

Jay

So, it's having that whole project in mind, so you can then do it in steps. And that's, for me, part of the business case to show: this is where we want to get to, this is the future. That's the approximate value that it'll bring but, at the minute, this first step of bringing very accurate data, this is the cost saving, this is how much it'll cost, this is your ROI.

Phil

Skills, Roles and Responsibilities

The impact on the roles, responsibilities and associated skills within the organisation was an area that each participant considered. The impact was considered across a range of areas, such as which skills to insource or outsource, the participants' own individual skills, and the skills of subordinates and senior managers. The literature identified that skills were the determining factor in adoption of Industry 4.0, and underpinned other barriers to organisational adoption (Karadayi-Usta, 2018).

Mitch also raised a general concern that introducing technology can also increase non-value add activities.

Fantastic for a while, and then you get to a point of, "Well, actually ..." Be in a culture, where people actually think that clearing their emails is their job

Mitch

For some of the participants, they recognised that they did not have the required technical skills to implement Industry 4.0 technologies. However, when Ned put his proposal to his line manager, he highlighted the commercial and management skills that Ned would bring to the implementation project.

But what I will do for you is figure out what use cases we can meet through the application of this technology, figure out the costs and benefits of doing so, and then implement it in a programmatic way.

Ned

As a result, Ned's project included the need to buy in the skills required.

there are lots of folks out there with the outline of a system, which they will essentially build for you on a bespoke basis as your needs become clearer. Now, there is benefits to that, because you can actually get what you want. The downside is clearly that it could be real expensive getting there. Yes, I don't really understand the IT, but I'll get people that do

Ned

Jay's approach also included the requirement to buy in the skills needed.

Right now it's looking at the autonomous market and that just needs a bit of external input, because we don't have a massive amount of experience in it.

Jay

In contrast, Phil's implementation pathway would have required existing employees to change their skill sets and responsibilities. He was facing some resistance due to concerns about technology replacing people. He was aiming to educate his workforce to change the mindset, which he supported by seeking out real life examples to share back with his team.

The thing is, it's not about replacing jobs, it's about enhancing jobs. And there was ... I'm trying to think, it was at the MTC, I can't remember the name of the company […]but he's the chairman of a company and they, for example, had an accountant and they've automated a lot of her job. But then they've not got rid of her job, they've moved her into a different sort of role using digital, training

people in digitization and looking for other ways to improve processes. But yeah, I think that's going to be ... but going back to your question, what I thought about is when you bring this technology in you need to spend a lot of time training people to help them to understand, help people to understand what the benefits are. It's not about job replacement, it's working with the robots and not against them, so to speak.

Phil

Phil's view of 'working with the robots' is supported in the literature by Giustiniano who advocated against a race against the machine mentality (Giustiniano, 2018).

Mitch also proposed an implementation model that utilised skills from outside the organisation. He described how the decision to hire short term consultants or permanent employees was based on how close the technology was to the day-to-day business operation.

The consultants would be on the bigger ship stuff and might help with that. Very rarely would we have them in the operational excellence piece, because that was all about ... Still, big changes, but they were always a progression or adjacent to what we already did. You want to make sure you've got people to do that. It was generally internal.

Mitch

The consideration of whether to develop skill internally or externally was also shown by Cam; the deciding factor was whether an external skills base would positively impact the business case.

I think in many cases it's likely that we would have a third-party but that would be on the basis that they'd help us either commercialize or take to market more quickly or more credibly a solution, not the fact that we wouldn't necessarily need it. We wouldn't need a third-party. We might elect to have one.

Cam

This approach supports an ambidextrous strategy, identified as an enabler in the literature. Engaging a third party is also an example of open collaboration, which is also a proposed enabler (Rogan & Mors, 2014) (Kohnová, 2018).

Cam was able to have this perspective on external skills due to the pace of adoption within the organisation; his perspective was that the demand for new skills was being managed at a pace that enabled employees to grow into new roles and responsibilities.

We are making moves on that journey and the changes to the organizational structure and skills tend to have been fairly modest. I don't think ... We're able to adapt to Industry 4.0 ... The organizational structure and skills can adapt at the rate of adoption that we're currently seeing.

Cam

Some organisations also focused internally on developing proprietary technology. The decision to develop internally or not was based on the business case for the technology, as well an assessment of competencies withing the company.

Particularly bearing in mind that it's actually quite a competitive landscape, there's a lot of people already doing this. So, you spend a lot of time and money and you might actually only get to a point that somebody's at already. So, one of the things [organisation's] quite strong on is partnerships and what they call co-creation. So it might be that a partnership, a license deal or a white label on a software is a better approach rather than developing our own.

Cam

Role Retention

Mitch also shared that he was aware that some industries are expecting to replace jobs with Industry 4.0 technology efficiencies; he was sceptical about the claims that the job levels would recover due to more equal wealth distribution creating higher demand eventually.

They did acknowledge that employment within the industry would actually come down to begin with, but then inevitably, would be richer and more people would have them, and therefore, it would all come back up again. It was all just a presentation that was all about convincing people that in the automotive industry would be lots of jobs that would go, and then there'd be more jobs in the end. Something like, because people who are a bit wealthier and more people that have cars, therefore ultimately, there would be more jobs in the end, which I didn't quite see.

Mitch

The participants spoke at length about the challenges they were facing getting their wider organisation to buy in to adopting Industry 4.0 technologies; the challenges differed based on the position of the employee in the organisation. Phil experienced resistance from subordinates that seemed to be based in the fear of their roles being made obsolete by the technology.

As in ... because also, as well, I've persuaded, I've talked to my boss about it and what benefits it can bring, but there'll be a lot of people on the shop floor who are like, "Are you trying to replace our jobs?"

Phil

He didn't have a clear plan to address the resistance from subordinates, but he appeared to intuitively tend towards educating the teams on the benefits of the technologies.

it's not just the senior management team but people who work on the shop floor, the technicians and everyone, because they think they're going to lose their jobs. It's helping them to embrace it and understand it, and I think a lot of training or informing them somehow of the benefits.

Phil

The participants shared that their senior management teams also needed education and support to fully understand the role that Industry 4.0 technologies could play in the organisation. In the case of senior management, the concerns were related to commercial impact regarding the feasibility, scope and return on investment.

lot of it is people's understanding of what it is and persuading people that it's not pie-in-the-sky ideas, and it can actually be something that could be very beneficial to the company. I think it's getting the senior management team on-board to actually understand what it is and how we can introduce it.

There was recognition that it is a management responsibility to ensure that nonvalue added development projects are stopped as soon as they are not commercially feasible.

At the same time, trying to make sure that things aren't developed that don't add value and don't become pinned projects, and basically are sidelined and killed off, because again, there's an awful lot of that. A lot of people are incredibly enthusiastic about developing technology. But is there any use? It's nice and it's interesting

Mitch

However, stopping projects before they are fulfilled comes with the risk of disengaging the workforce.

You can lose the organization and the people within it as well when you sit there and go, "What the hell are you doing? This is never going to work." That gets into the whole thing around the strategies around 4.0, about how do you actually engage a workforce, an employee base, how do you engage them and in terms of driving it forward.

Mitch

A suggestion was made that Industry 4.0 changes should be introduced in organisations by lower levels of the organisation. This was proposed with the caveat that may organisations would find it difficult due to it requiring a new 'mindset'.

a dilemma facing a lot of businesses or the modern-like of businesses. It's actually a very powerful thing, because I think the mindset of senior management or the exec team, or whatever you want to call them, I think if you try and drive that philosophy from the top you'll strangle it, and it will work. Ultimately, you really do have to let go of an awful lot of that, and you need to let groups and individuals within the organization to actually develop and trying to. That's a completely different mindset

Mitch

The ground up approach to implementation contradicts his previous statement about stopping projects before fulfilment if the senior managers don't believe it would be commercially viable. Mitch also identified an additional factor that might contribute to the perception of the commercial feasibility, cynicism. He recognised that cynicism can be a particularly hard barrier to overcome, with business case data and education not necessarily being enough to bring engagement.

Or, even just cynicism around, "Look, I don't see how this is going to work, and therefore, it's never going to work." The people who've got the mindset, "It's never going to work." Doing the maths, that's what's going to happen. You can't force it through. You can't actually say, "Well, I'm going to send you ... I'm going to do lots of social media and send you lots of emails, and you will implement." It wouldn't work.

Mitch

Organisation Structure, Systems and Culture

The methods used to find specific technologies varied between participants and were heavily influenced by whether the organisation structure supported the effort. In some organisations, there was a specific group tasked with 'horizon scanning', an externally focused activity.

We have a head of digital manufacturing; we've got a load of future technology guys… And their purpose is to evaluate technology, to assess what may or may not be of use to us in the future.

Ned

they've got this innovation practice which is intended to look at horizon-scanning of new technology and, in fairness, there's a fair bit of activity around machine learning and other types of those sorts of projects

Cam

The way the organisations shared the knowledge of the technologies was highly varied. In one instance, a participant was aware that although there was a team evaluating technologies, their evaluation criteria did not overlap with his and he struggled to access their knowledge formally. He countered this by building strong interpersonal relationships to work informally.

We have a very small digital manufacturing department and there are folks just like me out there thinking in a very similar way that I am, and we're not formally connected at all, but we found each other…
There's loads of stuff going on elsewhere… There's a long history of it, but it's not necessarily, it's not expanded from the center to the periphery, and perhaps with the speed and oomph that you had hope it would have… Core business, it's inherent in some core business activities, but in the support activities, not so much. But yes, islands of activity.

Ned

The use of a cross functional committee to decide whether to invest in a technology was common amongst the participants. A key part of the review was focusing on the commercial benefits and potential return on investment.

They would come in through the strategy in the M&A group, but people were encouraged to, "If you find something, then put a business case together, work with the ..." So, "Is it all strategy? Does it fit with what we're trying to do and the M&A people around if we are going to do this?" Then, if we come up ... Well, come up to me and others on that committee to either give it the yes or no.

Mitch

Within the innovation team there's a kind of regular forum where new technologies and any of these investments are probably categorized and subject to investment review before they go ahead.

Cam

However, Ned highlighted a barrier within his organisation from the IT function
Oh, a huge amount of barriers. They are starting to get to grips with how they need to respond to IOT and industry four. I'm not on my own on knocking on their door. I spoke to you earlier about the coalition that exists out there. Everyone's knocking on IT's door saying, "hey, I want to do this" and IT are going like "yeah, I get it. I see why. Right now we don't know and we cannot agree on what an appropriately secure way forward for you is".

Ned

The participants who were engaged in these activities were enabled by being part of an organisational structure that trends towards cross functional, flatter hierarchies; the literature identified this structure as an enabler (Miorandi, et al., 2012) (Deloitte, 2015). However, Jay perceived that he would personally need to be convinced of the value of investment, rather than a cross functional review.

You have to convince me that I've got to take masses of core space out of my organization, for me to worry about investing a million bucks in a technology that, today, is of no relevance to the profit they'll make.

Jay

The organisational culture and support shown by senior management was also referenced by participants; Ned shared that his management created a psychologically safe environment to allow for failure as a learning experience.

No, not necessarily. We're talking a lot about 'fast failure' here at the moment and it's okay to fail, but try not to spend three years doing it.
There's risk associated with it, but for previous reasons, you're not on your own in this. There is a lot of, I'm going to call it support, out there which should prevent the worst excesses from occurring.

Ned

The culture within Cam's organisation was supported by senior managers openly stating their support for innovative products and highlighting the importance of digitalisation for the organisation's success.

I think a tangible way they show their support, one, by there's periodic business updates. It's repeatedly mentioned, the support for not artificial intelligence in itself but the digital products and innovation is kind of called out separately. Digitalization is seen as a differentiator for the business. They show it by mentioning that and being consistent in that messaging I would say.

Cam

Some of the participants discussed how they prioritised technology implementation; one of the common ways of deciding was by using a Six Sigma tool, a lean prioritisation matrix. The participants also looked at partial implementation strategies e.g., semi automation as an intermediate step.

a Lean Prioritization Matrix to see the cost, how easy it is to implement, versus the cost and then decide from there what we go after to start with. What I'm trying to do is go after the low-hanging fruit first, like the wall thickness, I think that's going to be one of the easiest ones to auto- at least semi-automate.

Phil

Other participants took their prioritisation from the organisation's objectives or current challenges.

if I look through the list of problems that I have to go and solve, as a business lead, to deliver the business commitments that I have made or the margin commitments I have made, it isn't going to be [Industry 4.0]

Jay

Identify any additional enablers or inhibitors that are impacting strategic leader behaviours in the Industry 4.0 context

Industry 4.0 Scepticism

Some participants displayed scepticism when discussing the potential impact of Industry 4.0 technologies; they had difficulty giving credibility to the pace of development and implementation, and the level of responsibility that could be given to technology.

Do I really believe that we'll ever be at a point where 90 percent of decision making isn't me, and people like me, that understand the problem? Maybe, but it's a long way away. I don't know that I'll see it in my lifetime.

Jay

I think the whole 4.0 is a way of bringing a whole range of a variety of different things, moving it. Most people also talk about, "Well, this is moving faster than anything's ever moved in the past." Well, some of it is. Some of it is, absolutely, but by its very nature I think as technology and the whole efficiency piece, and the application progresses it's naturally all going to get faster. It's not going to get slower.

Mitch

I think there's a common misconception amongst many entities that if you sensor instrument up your equipment you never have a failure. That's obviously not the case. You always have failures. You're just intervening before they end up being a catastrophic event. Simply by instrumenting it up it doesn't mean you're not going to have to go in, work on equipment, and have people there. You're just going to have to do that a bit sooner.
there's relatively few clear-cut industry-endorsed examples of, "Yeah. That really, really worked."

Cam

In Cam's definition of Industry 4.0, he had focused on the use of sensors on equipment. However, when discussing the opportunity for using data, Cam highlighted that valuable data can be created without the use of sensors. He referred to the technology that he had developed to analyse non-sensor data and stated that it was the value of that analysis to that could create quality customer service.

It's not sensor data, but there's an awful lot of value in that data and that's what the technology that we developed prior to becoming acquired by Lloyd's works. So there are data sources that exist that allow you to do an awful lot of analysis and understand the equipment condition that doesn't rely on having a sensor feed….using that data does help you understand an awful lot about how your technology's working and how the customer's working and therefore help inform the future roadmap for technology development

Cam

For Ned and Phil, their mistrust was related to their challenge to understand the terminology and underlying technologies that the suppliers are offering. Some participants discussed the levels of trust that they had in the available sources of information, and any reservations they had about the information being supplied. A theme that emerged was the perceived motivations behind the entity sharing information. Suppliers of relevant technologies were viewed with mistrust.

real challenge or the real risk, really, at the moment on the client side is having the ability to accurately discern what's useful and what's not. It's very difficult. There's a lot of potential snake oil salesmen out there. Everyone's got a system. Every system does everything, or it could be configured to do everything. And truly understanding what you're buying, what its capabilities and limits are is massively challenging.

Ned

It's a great moneymaker, not necessarily for the customers
it is a scary place that is consultants trying to scare you into buying all sorts of stuff

What I've observed, is there's also individual companies or organizations with certain themes within all of this. That, they're actually trying to promote, which is not necessarily an unbiased view

Mitch

Participants referenced some external platforms that they had more trust in such as the Advance Manufacturing Research Centre (AMRC), Manufacturing Technology Centre (MTC) and IBM Corporation. One participant referenced the World Economic Forum as their main source of information. The participants' views were that these organisations were more credible. In the cases of AMRC and MTC, credibility was enhanced due to government association.

Researcher: Did the fact that they are a government backed institution help?
Phil: That's a really good point. Yes. Yeah, definitely. By the fact that you feel, one, cozy and confident that they will provide a good service than if it's just a random company or consultant, sort of thing

The AMRC, we've been over there, had a look around the factory there and talked to them, but they've not been as quick to get back to us as the MTC. I know they're all part of the category, we'll call it the scheme, I suppose, but yeah, MTC have been great so far. I mean I am talking to other people and there are other potentials, like ... especially tomorrow, I'm going over to the AMRC to meet with IBM and they might try to sell a solution. I may be interested to see ... of course they've got IBM Watson and all that sort of thing, that and IBM are credible, so that's another good potential.

Phil

I had an invite... I could kick myself because they did a... IBM did an open day down in, was it Winchester or something like that, relatively recently. I was invited, but I couldn't go.

Ned

A factor in scepticism was also the impact of the physical environment that the technology would need to operate in, and the cost benefit analysis of installing the technology. The participants who worked in the Oil and Gas Industry stressed the challenging physical environments that limited the application of Industry 4.0 technologies.

Because if this is your piece of pipe, if you want to put a sensor on here, you can't drill into it because it contains the fluid that's dangerous. And to do so would mean shutting down and it would cost you millions and millions. So the benefit from doing that is modest…You do get temporary sensors, but because of the hard environment they fall off. And then connecting the sensors either requires something cabled, which again is a very expensive job, running cable, or you can use wifi type technology. But, because when you're oil and gas offshore, a lot of the communication... there's a lot of qualification of communication protocols to prevent things like emergency response being degraded. In a small number of facilities with fiber optic networks, a lot of them are satellite controlled so actually getting data backward and forwards, quite a challenge in terms of bandwidth.

Cam

Stakeholder Expectations

All organisations operate within the parameters of their industry, where they are influenced by their customers, stakeholders and competitors. One of the factors that influenced the organisation's Industry 4.0 activities was the expectations of their stakeholders and customers. In Mitch's

organisation, it was an investment requirement that a company had to have a strategy for utilising Industry 4.0 technologies.

The interesting thing was the private equity company in question basically has a mantra inside a business, which is, every single business that they invest in must have a digital strategy.

Mitch

Using Industry 4.0 technologies is now perceived as an aviation industry expectation.

I wouldn't say it's a differentiated force, that's where the industry has moved. So it's an expectations that that's what we do, too.

Jay

Cam highlighted that Industry 4.0 has a certain prestige to it, which companies use to market themselves to customers.

I think part of this as well is to be active in Aberdeen and to be attractive to some customers, you need to have a presence that's of a certain type as well.

Cam

This point was echoed and further highlighted that the perception of what the organisation is doing is important even if the actual complexity of technology is quite low. He shared his assessment that not engaging with Industry 4.0 meant that an organisation was vulnerable to competitors.

It's the thing around with a lot of this stuff, it's around the words, buzzwords, and people's perception of things. Ultimately, if you don't have a, whether it's a formal, or an informal, or you're constantly thinking about it in any sort of business, then ultimately you'll get overtaken by the competition in one shape or form. For that, I think that's ... In my mind, I think it's a given. But, it could be anything, from extreme cutting edge technology, down to pretty basic stuff.

Mitch

Phil and Ned highlighted that the accessibility and use of connected technology in personal lives were contributing to increased customer expectations.

the whole ordering process more efficient. Customers then can quite easily, oh, I'll just order something. Just like when using an Amazon app. It's so easy to buy something on Amazon.

Phil

people are getting, they're moving away to the point where just people expect stuff to just happen. And I think Industry 4.0 and IoT can start to get us down that trend.

Ned

In the case of Jay's organisation, the fact that the customer did not require improved data analysis meant that artificial intelligence was not viewed as a technology that would add value.

The nature of what we do and how heavily tested and certified and scrutinized everything is, that kind of next generation of technology, it doesn't particularly exist in our business, because what we do is so heavily scrutinized and tested. So I guess no reason why not, but if I think about, do we really deploy any super intelligent technologies that make decisions for us and we just trust in the fact that that's okay, of them sifting through data automatically. It's not our industry.

Jay

Jay highlighted that their organisation already collects data from customer assets as a proactive

customer service.

we suck data off the aircraft as it's coming in to land. And that wasn't in response to a problem, that's because that lets us solve a customer issue.

Jay

Cam shared their experience of industry wide trends changing the priorities for their customer base, creating the opportunity to prioritise new technology in response.

What happened was I think that there was quite a nice turn of events where the oil price went down, increased the pressure on companies to reduce their cost base and the software, the technology, in the main was able to help them do that. So if you went back in time there wasn't the same commercial pressure or need for the technology I think.

Cam

Additionally, the building of new facilities was also seen as an opportunity to prioritise new technology, rather than retrofitting existing facilities.

For new facilities that are getting designed I think as an industry we're quite slow to adopting the benefits of the industry for building that in. This is kind of an industry that's steeped in tradition and the way that things have always been

Cam

One feature of using Industry 4.0 technologies to interact with customers was the risk of increased customer scrutiny due to the live nature of the data. However, Phil was optimistic that the increased efficiency of Industry 4.0 would mean that there would be no causes for customer dissatisfaction.

I think it'd be beneficial as well to actually ... we'd have to have a pros and cons, weigh it up, but to be able to show that customer order, where it is in the factory. I mean it might cause problems if a customer looks at it and goes, oh-Why isn't it on time? But ideally, with the whole process, you should have, everything should be on time. If we're using digitalization, we shouldn't get, we don't have those problems.

Phil

Role Creation

The participants shared examples of how the creation of new roles supports or limits adoption and utilisation plans.

Ned's role was a newly created post within his organisation; the scope of the new role enabled him to network and challenge existing work practices.

so this role's turned up. It is multi-disciplinary so I get to go along to loads of different meetings I never went to before and I'm making connections between people. I'm finding, I'm finding shared gains that no one was doing before and it was so easy for someone to ignore something that they probably knew was right, but it was still slightly peripheral to what they were doing.
And again, perhaps we were guilty of 'tick-box' project management, you know "that building needs to have a building management system". "Does it have a building management system?" "Yes it does". "Great." Whereas that's not the right question.
"What's it doing?" "How's it work?" "What's it connected to?" "What are we doing with that data?" And I think that's probably what's changed. I'm not going to take all the credit for this myself because as well as my appointment, there've been two asset managers appointed in the last six months, one in North America and one in Europe and the three of us are working very closely on a lot of these

things because there's a huge amount of overlap between what they're trying to do and what I'm trying to do.

However, he perceived an absence of a type of leadership role that he characterised as a 'shepherd'.

I've seen loads of people a bit like me out there, but there's no one, there's no shepherd…Lots of functions of appointed or given individuals responsibility in this area to deliver in that area, yet there's no cross-functional leadership…I think there needs to be guidance within the organization to try and make sure all of these activities are coordinated, they're aligned, they co-exist, they don't conflict, and they share where possible.

Ned

This need for this 'shepherd' type of leadership role was recognised and created in Mitch's organisation, with the creation of a new executive role for the business, a Chief Information Officer (CIO). Mitch emphasised that the person selected for this role wasn't the most technologically skilled applicant; they were chosen for their ability to assess the technology against the business need.

The other thing we did as well, is we hired a CIO that had nothing to do with ... had never had anything to do with engineering. His background was supermarkets, because we really didn't want a CIO who had always picked stuff, his or her, so it happened to be his. We didn't want somebody coming in going, "Well, the last place we implemented this it was fantastic." It was all about trying to get somebody, who really was willing to look all sorts of things and select what appeared to be the best solution for the issues or where we wanted to go.

Mitch

The roles and responsibilities of the CIO were focused on the business need for information and correlating that to the investments required. The role also provided company employees with a pathway for proposing new technologies. Mitch also highlighted that the CIO was well supported, with high levels of resource available to work on projects. The resource available was partially based in a low cost country. The remoteness of the team did not affect the quality of the work, with Mitch recognising the high skill level.

The CIO is really the person who drove more information systems and software, and the likes, as opposed to necessarily try and develop technology. When somebody developed or a group of people developed an idea on how to come up with a solution for something, then the CIO in the group would then look at is there given software solutions to be able to do that job, or are we actually getting into writing up a whole bunch of new stuff. Generally, we had a large team. Just about all the applications that weren't new and needed to be coded up and developed were actually done in India, and that sort of two. Now, I've found some people there who did that. They were just incredibly talented.

Mitch

Mitch also shared an example of commercial management responsibilities changing. Mitch's company bought another company to acquire proprietary technology

when we looked at the due diligence in the company, basically the due diligence was not the traditional due diligence around, "Show me your accounts, and show me this, and show me all that." It was really all around, "I want to see the technology, I want to see the software, I want to do the testing, want to do short-form testing and this to make sure that it works." Having the experts in

there to do that. Then, there's still a bit of a leap of faith around all of it, and where did you apply that.

Mitch

Macro Trends

Workforce Demographics

The engagement of the workforce was a strong point of consideration for the participants' Industry 4.0 plans; the participants considered that engagement was dyadic, and that there were several wider trends that were motivating the organisation's employees to engage.

One factor was the presence of technology in their employees' personal lives leading to greater expectations to use similar technology in the organisation. The participants felt that there was a clear generational divide in attitudes and engagement, and that this divide that would become more pronounced as the current workforce continued to age.

I remember seeing a little kid trying to swipe a television screen. They're used to that degree of interaction. The minute you picked up an... iPads are amazing things because that's so intuitive. You give anyone one of them, in three minutes, they've figured it out. At least, they can use on a base level. Work should be like that, and IoT and Industry 4.0 can make work like that.

Ned

I think especially for the aging workforce, I suppose. Definitely people coming out school nowadays are going to be growing up with iPads and iPhones, and everything, so they have a better ... especially with Facebook, Twitter and everything, they can understand technology a lot better than the aging workforce. I think the younger engineers understand it a lot better and are on board with it a lot more. And are interested and sort of ask questions. "What's this? What's going on?" All that sort of thing.

Phil

In addition, Phil suggested that part of the resistance to re-skilling was generational differences. His workforce was predominantly older employees who had not faced a lot of change in their role previously. The challenge that Phil identified was convincing these employees that they were capable of learning still.

And to introduce something completely different, it's going to be, one, they have to re-train, which a lot of people are like, "I've not learned anything since university, since school."

Phil

As a result, he thought that the approach to reskilling needs to account for the individual's baseline competency with technology in general. As the demographics of the workforce shifted to include younger generations, he expected technology acceptance to improve.

No, I think especially for the aging workforce, I suppose. Definitely people coming out school nowadays are going to be growing up with iPads and iPhones, and everything, so they have a better ... especially with Facebook, Twitter and everything, they can understand technology a lot better than the aging workforce, especially people who have just been in the same or similar job for most of their career where they've worked with ... Or even people who sit behind a desk with a computer, they'd be used to using word processor, Excel, sort of thing.

Phil

Mitch felt that the new technology management positions may not be as open to female applicants, due to the innovative nature of the role itself taking some organisations over their risk comfort threshold.

There's also, which is maybe something to do with it, so the culture and the behaviors piece in terms of 4.0, because some of the themes are the same. There's this piece as well around the selection process. People never really got fired necessarily for selecting the guy who didn't succeed, whereas I think people thought it was more risky to select a woman who subsequently didn't succeed.

Mitch

Increased accessibility to technologies

Increased accessibility to technologies also influenced the participants and their organisations.

Mitch shared an example of a company he evaluated for investment. The company did not have a digital strategy and were concerned about the cost of implementation. Mitch shared that they were surprised by how cheap the sensors were and immediately agreed to implementation.

Well, how much is this going to cost?" "Well, £0.49." "£0.49 pence? Well yeah, we want to do that." I said, "Okay, so you do have technology, or you would like to have technology."

Mitch

Phil also shared an anecdote about how accessing some of the foundational Industry 4.0 technology motivated his engagement. By using a Raspberry Pi for his hobbies, he was able to understand their function in collecting data in industry.

I made my own computing system using a Raspberry Pi. So all the old Sega Mega Drive Nintendo games are all on the little things that I made for Christmas presents sort of thing. And a Raspberry Pi tends to be used as, from what I've seen at the AMRC, they're using a ... it might have been the Arduino and the Raspberry Pi, but using them to just collect data off of an old lathe, so stuff like that is so simple.

Phil

Sustainability

Sustainability also emerged as an external factor that affected the participant's own motivations for engaging with and championing Industry 4.0 technologies in the workforce.

The carbon question. Our base products today will not be acceptable within the next 50 years. Carrying on manufacturing gas turbines is not an acceptable longterm strategy. Maybe 20 years of it left, maybe 30. I can't really see us making many fossil fuel-fired planes flying in 2050 can you?

So we have to use technology to find alternatives which are acceptable from a carbon point of view, but still enable us to meet all three core business objectives

Ned

Ned also felt strongly that the focus on sustainability was widespread, and not necessarily led by one stakeholder. He reflected on how his own concerns on sustainability have been embedded within the organisational culture.

I only don't feel like we are the 'green evangelists' anymore, whereas I spent probably the first half of my career being 'the green guy' and I doesn't feel like that anymore, which is really interesting. I'm kind of cool handling that mantle over.

Ned

You've got an aging, not aging, you've got an exponential growing population of the world, food, water, all that sort of thing, and if we invested more in technology for manufacturing, and food growth is a type of manufacturing. So, if the government actually invested more of GDP into technology and science I think it would be very massive for the future, and to actually ... I think we need to do that, so if we're going to want, not just for manufacturing, but just for surviving on the planet as humans we should invest a hell of a lot more in technology.

Phil

Impact of Covid-19 Pandemic

The participants were interviewed prior to the Covid-19 2020 pandemic. However, due to the impact of the pandemic on organisations, the participants were invited for a further interview to reflect if they and their organisations outlook on Industry 4.0 had changed. Phil and Ned took part in a second interview; however, the audio recording for the interview with Ned failed. The researcher has added observations from their notes from Ned's interview to supplement the data extracts available.

Skills, Roles and Responsibilities

In the first interview, Phil had highlighted that he was facing a challenge with getting the sponsorship from his senior management team, which was related to their skill and knowledge of Industry 4.0. Phil widened his approach to include senior managers from other, more indirect functions. Phil shared that he has seen senior managers waver in their buy in, which he overcame by connecting them with external experts to address concerns.

I had to get the engineering manager onboard first. And we had I think two sessions with their IBM guy, expert and lots of questions. One of the calls was kind of like he went backwards, and I was like now what's he on about? There's definitely, this is definitely going to work, this is the easiest solution for now.
Researcher: Why did he go backwards?:
I think he was just unsure because he had lots of questions, it's been two months now, but he had a lot of questions, and he was just basically he was unsure about things. So I went, I spoke to him after the call and talked through his concerns and he ... and I was like look, we'll have another call with him and confirm, I'll email him now and just confirm now that it will be able to do what you're worried about. And the guy came straight back and said yeah, I can do it, we'll have another call and I'll talk you through it. So he did that and then he was fully on board with it

Phil

Phil was finding that he was making progress with his widened approach; the impact of the pandemic means that he thinks he will have lost some of the momentum that he was building and

that he will have to re-do his engagement efforts. Phil also noted that the senior managers with enthusiastic support are 'fairly young'; previously, Phil had noticed that there appeared to be a variable level of support from his subordinates that was correlated with their age.

So I did, I spoke to the sales director, and he was fairly young, he was probably about 40. And he was dead impressed, so he was like, do you mind next time, because every month they have a monthly sales meeting discussing different things. But then they have someone who tries to keep it a bit different and he has someone from a different department come talk about something different. And he wanted me basically present that same sort of thing, those slides to his whole team. So I did that, and the were ... I thought oh yeah, loads of questions, and all of course very excited and very interested. So it was starting to move in the right direction, but it's kind of ... probably I'm going to have to engage people and how well they remember and their interest in it when I go back, and start getting people interested again.

Phil

Phil had also made progress with selecting suppliers and partners for his project; IBM was selected and hosted a 'garage' day of demoing technology to senior managers. IBM senior leaders were also present at this 'garage' day.

I took my boss, the engineering manager, the logistics and purchasing manager, yeah that was it. And we went for the day and spent the day with loads of top bods from IBM from different areas, experts in IoT and others on purchasing. Different things like that.

Phil

Phil also made progress with building support in his direct line management, although he acknowledged that his boss was still hesitant and that it took a few attempts for Phil to be able to convince him.

[my boss] he's very on board with it all, it took me a few ... about two one hour meetings with him, presenting, I think I sent through some of the slides that I presented to you, to him, to you. And talking through what Industry Four was and all that sort of thing. And I think going down to the IBM got him on board a lot as well. And so he knows that's the direction we need to go in. Still a bit nervous about things.

Phil

From even more senior levels of the organisation, Phil was given encouragement and told to focus on connecting to people within the organisation.

I did also give, again I can't remember if I told you about this, but I did speak to the ... a guy called Tony Edwards, anyway he's my boss's boss's, the deputy president, some big title like that, he said, don't be phased by people who are not interested, just keep pushing, keep persevering, talking to the right people.

Phil

Phil summarised the aim and impact of the networking that he is doing.

it's having that influence that that those ... getting everybody on board. And in know that's probably something that we've talked about before, but yeah it's getting people interested and getting the enthusiasm to take it on board and understand it and want to be part of it

Phil

Previously, Phil had acknowledged that the presence of his predecessor was limiting his ability to build influence. The COVID-19 pandemic did not directly trigger the retirement taking place;

however, the step change of returning to the office from lockdown presented an opportunity for Phil to return fully in position.

I don't think ... it definitely didn't straight away, but I am actually going back on Wednesday as the manager, taking on officially ... yeah I'll be officially in that position when I go back. But yeah, no that should definitely open ... help things move along a lot easier because I'll be going to all the senior management meetings and all that good stuff to know what's going on and who to ... or when best to push things, et cetera.

Phil

The pandemic had impacted the timeline for implementation of technologies, due to furlough.

I'm wanting to improve things, and definitely will be pushing the industry four technologies. And as I left it, I had five potential projects being early stages, being worked on to move forward with. One of them, probably about a month before I was furloughed, was given the green light and that was to basically start using Dashboard, and this was through IBM.

Phil

However, Phil did not see that as a major barrier. He believed that the pandemic had created more scenarios where Industry 4.0 technology could be implemented.

I think even more so with the pandemic because if you can automate more things where they don't have to be come in close contact or onsite would be beneficial. Some of the things we were talking about with IBM, because when that first month after we were lock down started they were starting to think about how their services could help with keeping two meter rule, keeping people away from each other, but yeah definitely I think that's very beneficial.

Phil

The pandemic did not affect the prioritisation of Industry 4.0 projects; the first project approved was to replicate an existing process by sensoring the equipment.

it was more guided by ourselves, I think the first goal was to get the current set up, and the current sensors onto the system. But then it was, yeah more guided by ourselves and wanting all the critical parts of the process to start looking at that, and probably more earlier on parts of the process

Phil

The project had been attempted previously, but was not successful due to incompatibility between sensors and the systems. The confidence to try again came in part from trust in IBM.

he did install it before I started working at the company but my manager wasn't ... of course they'd spent 14K and got nothing out of it. But hopefully the idea was this system, a very simple system that IBM was offering would be to be able to use that data but then also start putting simple vibration sensors on machines and current sensors, simple things like that

Phil

Phil and the management team agreed an investment approach; a budget was identified to get to proof of concept, which would then be used to get wider engagement from the highest level of management in the international corporation.

David my boss was quite, yeah you think, if it makes sense then I ... he did say to us, and he said this at the IBM meeting, he's happy to sign up the 30K off, but not really going into much detail, and the return on investment, it's just getting things off the ground.[..] it's almost like he wants a proof of concept and prepare to spend up to 30k-ish just to get some proof of concept on the shop floor, and then he can take the big [inaudible 00:22:41] the CEO round the shop floor and show him, look this is this, this is the benefit it gives. And then get board approval for the bigger investments.

Phil

Previously, Phil had discussed the challenge of selecting appropriate partners for the projects and technology. IBM was selected as the key partner, and Phil stressed the importance of IBM taking the time to build a relationship with the leadership team and showing how they could help their specific business. IBM also demonstrated their competencies by sharing case studies from other organisations. However, Phil also acknowledged that the investment IBM required was higher than expected.

all the experts that I went to, they ... one of the ones that I think played the long game, showed the interest, didn't push anything too soon. And they did ... I don't know if you told you about this, but we went down to London, this was about January time, we went to London and we did what they call a IBM Garage, and it was literally a day[..]And then used that day to push us in the right direction to highlight different projects to work on, that they could support us with. And so they did that all for free, and that was very well done, very interesting, and of course you've got the backing of IBM as well. And they've got some good examples from implementing it at big companies like ... I think one of them is L'Oreal. I think they've got ... they have got YouTube videos of what they've done. So there's one at L'Oreal but then was one at a small beer brewery in North Carolina in the States. Sugar Creek Brewery I think it was, and they just used IoT industry floor technology to monitor all different things, from the amount of beer going into bottles, things like that. To reduce operating costs, and that was quite a small set up so it the arguing that they work with the big guys and all the way down to the small guys. […] Well they've been a good, they've a good selling point at that. And they didn't tell us any of the prices up until the point until they sent us a quote through. And then the quotes were quite high, it was like oh

Phil

Throughout the pandemic, Phil knew that there were online conferences available but did not attend any, in contrast to his activities prior.

[Did you attend any online conferences or similar?]
I didn't no. I did actually sign up for them, I got the emails for them

Phil

Phil's viewpoint on the impact on the skills for his subordinates had not changed; he still foresaw the need for people to be retrained due to the technology replacing their role. However, he was notably less concerned with this as a barrier.

technology's going to replace their roles, once you can get over that and people can get up skilled and get other jobs that can enhance the value et cetera

Phil

Phil had also been focusing his efforts to ensure that IT skills were available to support his projects; the organisation's incumbent IT skills and infrastructure had been acknowledged as a barrier, and were related to a previous project failure. Despite IT recognising this, Phil did not observe any great momentum that made him confident in change in that function.

January time we got a new guy, and he seemed very interested, very keen in the Internet Of Things and all that sort of thing, and he came and said, I've got a server under my stairs that runs faster than the server, I was like, that's promising then.

So that's a challenge in itself, I did sit down, before this pandemic stuff happened and the IT director was over, I did spend an hour with him presenting something similar to what I sent through to you, to him again. And he had similar ideas, I think he's definitely a bit old school, but he's definitely thinking in the same sort of ballpark, of wanting to move things long, but it seemed a lot, I couldn't see anything happening quickly.

Phil

Phil stressed why he believed IT skills within companies were important, and personally acknowledged his commitment to supporting change in that function.

Do a lot of stuff ourselves, so not relying on companies like IBM to ... if there's things need changing or updating or improving. Yeah but someone like that but then also having an ITT that understands the system and works with us, and not just there to sort people's computers out but actually sort of yeah. But that's going to be ... over the next year to two years I think's going to be part of my personal ... will be pushing for that sort of thing to get some key assets into the business, bring some key knowledge into the business, to get that ... to help us and to push that forward

Phil

Phil had some observations on where he would seek skills from; he saw universities that had taught Industry 4.0 modules as valuable sources of skills.

In an ideal world, especially in the position that we're going to be in, I need someone working for a quality engineer, working for me, someone I would guess probably fairly youngish, like a couple of years experience under their belt would be ideal. I'm thinking he's got a bit of background in programming, and just a few uni courses with Industry Four digitalization in the title

We went to Nottingham University towards the end of last year, […] the selling point that a lot of their courses now have a lot of digitalization content in them, so again … anyway getting students in like that to help support implement of these things.

Phil

Additionally, Phil had used some of his furlough time to register with an online course that was also provided by IBM.

I started doing a bit of an online course on ... well I started it before lockdown but continued it a little bit on ... it's actually the IBM course on, oh god, I logged it for a week. But yeah I'm basically technology on IoT on digitalization. Just to working on that, be interesting if I can ... when I go back on Wednesday if I can find time to finish that off.

Phil

Phil remained focused on the impact of age demographics on the organisation; he acknowledged that the imminent retirement of key leaders would lead to a loss of knowledge and skills. As a result, Phil was trying to seek these leaders out to learn from them prior to retirement.

some of the stuff we've been doing, the same stuff we've been doing for the last 30 years. It works but how long we going to stay there, it's ... we need to start moving forward. And I don't ... there's quite a lot of ... the production manager's probably getting ready to retire in the next six months to a year. And there's some younger guys that are very keen to see the technology come in,

I'm trying to think how old he is, but he's not near retirement yet but he is getting on a little bit. But for an older guy he does know what's going on, so it was made sure I could talk to him because he knew a lot

Phil

Phil also remained open to the idea that Industry 4.0 technology supporting sustainability goals.

... I suppose I'm always thinking about the future and how society and the environment can improve and I think if from an environmental side you can reduce your waste from everything that you put in the bin to the fumes that you're putting up into the air, I think if you can monitor that sort of thing and look for opportunities to reduce that, then it would be very beneficial

Phil

As a result of the COVID-19 pandemic, Phil was more sensitive to the potential health risks of their industry and felt an increased sense of responsibility.

and so they're not doing, and those jobs will hopefully be a lot safe so they're not working in dangerous environments where you can automate the processes.

I want to be a good manager and keep the respect from my ... the guys that report to me.

Phil

Summary of Findings and Integration into Hierarchical Taxonomy of Behaviours

The analysis of data gathered in this study shows that there are factors affecting the adoption of Industry 4.0, and how these factors are identified and managed can analysed through the lens of demonstrated leadership behaviours.Integration into Hierarchical Taxonomy of Behaviours

Yukl's hierarchy was identified as the most contemporary integration of leadership behaviour research, despite limitations such as a focus on behaviours most meaningful to subordinates, rather than leader effectiveness, and no clear link between the most appropriate use of behaviours on a situational basis.

Data in this study showed support for most of the behavioural subcomponents within the taxonomy; the behavioural subcomponents of recognizing and empowering were the most weakly demonstrated. This could, in part, be due to the specific interview questions and would benefit from further investigation.

External monitoring and networking were the behavioural subcomponents that were the most strongly demonstrated. Contingency theories of leadership behaviour and innovation would suggest that change based behaviours would be the most relevant; however, the participants sought out information and knowledge on Industry 4.0 prior to making the decision whether to encourage adoption or not. The participants that did choose to support change did so with a spectrum of enthusiasm, linked to how credible they perceived the advantages of Industry 4.0 to be.

The study identified specific taxonomy behaviours that the participants demonstrated in response to the specific challenges and opportunities that they perceived in Industry 4.0.

The participants demonstrated limited clarifying and planning behaviours; no participant was able to clearly articulate an integrated plan for adopting Industry 4.0 technologies. The participants who were targeting adoption had vague intentions, despite great enthusiasm. The participants' inability to clarify and plan the roadmap to Industry 4.0 adoption and integration was linked in the literature

and in this study data to a lack of definition for Industry 4.0 and its technologies. The lack of clarity was also connected to the participants' uncertainty about the evolving and interconnected nature of the technologies, which resulted in them feeling overwhelmed and unsure of where to start the roadmap from.

To overcome these barriers, the participants engaged in externally focused behaviours such as networking and external monitoring. They sought out information sources relevant to Industry 4.0 and their industry and networked with organisations and individuals who had useful knowledge. This knowledge was then used to clarify and refine their plans for Industry 4.0 adoption.

The level of skills and knowledge of the workforce was identified in one study as the main barrier to successful adoption of Industry 4.0 technologies (Halse & Jæger, 2019). The participants did not offer data in support of this being the main barrier, but it was an important consideration. The behavioural subcomponents of developing and supporting were utilised to aim to address barriers created by lack of understanding in the workforce; these behaviours were not only directed at subordinates, but also towards peers and management. Facilitating collective learning was also a behaviour that had relevance to improving the knowledge of the wider organisation.

The body of knowledge on innovation leadership highlighted the positive impact of ambidextrous strategies; strategies that focus on exploitation of existing processes and assets in the short term and simultaneously focus on more exploratory opportunities in the long term. The aim of the behavioural subcomponent 'facilitating collective learning' has the same underlying demarcation of activities 'improvement of current strategies and work methods (exploitation) or discovery of new ones (exploration)' (Yukl, 2012, p. 74). Data collected in this study showed that the participants were targeting ambidextrous adoption strategies, by focusing in implementing technology to support existing process in the short term and simultaneously exploring more 'blue sky' opportunities for the technology. However, there was no connection with their pursuit of this strategy and the behaviour 'facilitating collective learning.' When 'facilitating collective learning' was demonstrated, it was in support of knowledge diffusion in the organisation and developing the skills of the workforce.

Recommended Integration with existing knowledge

Alignment

Throughout the analysis of the data, the 2012 Hierarchal Behavioural Taxonomy developed by Yukl was used as an inductive framework. The taxonomy has been evaluated by the leadership behaviour research community as an integrated model of contemporary research, with researchers recommending that future research uses it as an anchor for the development of new leadership behaviour models and theories. The acknowledged limits of Yukl's 2012 version relate to its focus on leadership behaviours through the lens of subordinates, although this was somewhat addressed with the inclusion of the externally focused behaviour meta category. The taxonomy is also limited in its ability to guide practitioners in the application of effective behaviours; it is not linked to specific situations, does not indicate whether the timing or frequency of behaviours impact their effectiveness or whether there may be additive or multiplicative effects when two or more behaviours are used in pursuit of the same objective.

Through the deductive analysis of data gathered in this study, the subordinate focused limitation of the taxonomy became apparent as the participants demonstrated behaviours that did not fully align with the stated definitions or aims as captured in the taxonomy. This limitation was demonstrated most clearly in the task and relations based meta categories; the formation of these categories by Yukl leveraged studies where the predominant research methodology was questionnaires completed by subordinates on their perspective of leadership behaviours. In this research study, the objectives of the task and relational metacategories did not fully align with data collected, as the participants shared data that was related to their own tasks and relationships, rather than having a subordinate's perspective. As a result, this study proposes that the objectives for the behaviours are updated to reflect a wider perspective.

The table below shows the 2012 definitions and goals as defined by Yukl in comparison to the potential updates that could be made to reflect the findings of this study's deductive analysis. The inductive analysis of the participants' data showed additional behaviours that were not in the 2012 taxonomy but meet the criteria for inclusion as defined by Yukl. These new behaviours are also included in the table below, highlighted in blue.

Meta Category and Aim	**Behavioural Subcomponent**	**Original Subcomponent Definition and Aim** (Yukl, 2012)	**Subcomponent Definition and Aim, updated with the findings from deductive analysis from this study**	**Subcomponent Definition and Aim, updated with the findings from inductive analysis from this study**
Task Based Behaviours: 'to ensure that people, equipment, and other resources are used in an efficient way to accomplish the mission of a group or organisation' (Yukl, 2012, p. 69)	Clarifying	'ensure that people understand what to do, how to do it, and the expected results' (Yukl, 2012, p. 70)	'ensure that the plan will meet group or organisational objectives and that people understand what to do, how to do it, and the expected results'	
	Monitoring	'monitoring involves gathering information about the operations of the manager's organisational unit, including the progress of the work, the performance of individual subordinates, the quality of products and services, and the success of projects or programs'. (Yukl, 2012, p. 70)	'monitoring involves gathering information about the operations of the manager's organisational unit, including the progress of the work, the performance of individual subordinates, the quality of products and services, and the success of projects or programs'. (Yukl, 2012, p. 70)	
	Planning	'cognitive effort required to identify and plan the scope and execution required to support organisational activities.' (Yukl, 2012, p. 70).	'cognitive effort required to identify and plan the scope and execution required to support organisational activities.' (Yukl, 2012, p. 70).	
	Problem Solving	address the 'disruption of normal operation and member behaviour that is destructive, illegal or unsafe' (Yukl, 2012, p. 70)	address the 'disruption of normal operation and member behaviour that is destructive, illegal or unsafe' (Yukl, 2012, p. 70)	
Relations-based behaviours: 'to enhance member skills, the leader-member	Developing	'increase the skills and confidence of work-unit members and to facilitate their career advancement' (Yukl, 2012, p. 71)	'increase the competencies of all members of the organisation and support the development of roles and responsibilities that match the needs of the organisation'	
	Supporting	'showing positive regard, building cooperative relationships, and	'showing positive regard, building cooperative relationships, and helping	

relationship, identification with the work unit or organisation and commitment to the mission' (Yukl, 2012, p. 71)		helping people cope with stressful situations' (Yukl, 2012, p. 71)	people cope with stressful situations' (Yukl, 2012, p. 71)	
	Recognising	'providing praise and recognition for effective performance, significant achievements, special contributions, and performance improvements' (Yukl, 2012, p. 72)	'providing praise and recognition for effective performance, significant achievements, special contributions, and performance improvements' (Yukl, 2012, p. 72)	
	Empowering	'giving subordinates more autonomy and influence over decisions about the work' (Yukl, 2012, p. 72)	'giving subordinates more autonomy and influence over decisions about the work' (Yukl, 2012, p. 72)	
	Mission Matching			'demonstrating alignment to organisational values through transparent decision and evaluation processes'
Change based behaviours: 'to increase innovation, collective learning and adaptation to external change' (Yukl, 2012, p. 72) .	Advocating Change	'explaining why change is urgently needed, observable examples include similar work unit or competitors have better performance, explaining threats and opportunities, and undesirable outcomes if they are not responded to' (Yukl, 2012, p. 73).	'explaining why change is urgently needed, observable examples include similar work unit or competitors have better performance, explaining threats and opportunities, and undesirable outcomes if they are not responded to' (Yukl, 2012, p. 73).	
	Envisioning Change	'articulating a clear, appealing vision of what can be attained by the work unit or organisation' (Yukl, 2012, p. 73)	'articulating a clear, appealing vision of what can be attained by the work unit or organisation' (Yukl, 2012, p. 73)	
	Encouraging Innovation	'challenging people to question their assumptions about the work and to consider better ways to do it' (Yukl, 2012, p. 73)	'challenging people to question their assumptions about the work and to consider better ways to do it' (Yukl, 2012, p. 73)	
	Facilitating Collective Learning	'improvement of current strategies and work methods (exploitation) or discovery of new ones (exploration)' (Yukl, 2012, p. 74)	'improvement of current strategies and work methods (exploitation) or discovery of new ones (exploration)' (Yukl, 2012, p. 74)	

Externally Focused Behaviour: 'provide relevant information about outside events, get necessary resources and assistance, and promote the reputation and interests of the work unit' (Yukl, 2012, p. 74)	Networking	'building and maintain favourable relationships with peers, superiors, and outsiders who can provide information, resources and political support. It includes relationship building tactics such as finding common interests' (Yukl, 2012, p. 75).	'building and maintain favourable relationships with peers, superiors, and outsiders who can provide information, resources and political support. It includes relationship building tactics such as finding common interests' (Yukl, 2012, p. 75).	
	External Monitoring	'analyzing information about events, trends, and changes in the external environment to identify threats and opportunities for the organizational unit', also known as 'environmental scanning' (Yukl, 2012, p. 75)	'analyzing information about events, trends, and changes in the external environment to identify threats and opportunities for the organizational unit', also known as 'environmental scanning' (Yukl, 2012, p. 75)	
	Representing	'Represent their team or organisation in transactions with superiors, peers and outsiders such as clients and suppliers.' (Yukl, 2012, p. 75).	'Represent their team or organisation in transactions with superiors, peers and outsiders such as clients and suppliers.' (Yukl, 2012, p. 75).	
	Critical Evaluation	'		Evaluating sources of knowledge and information networks for credibility and value'

Table 7 Summary of findings, in comparison to existing behavioural taxonomy

Restructuring of existing behavioural structures and creation of new behavioural metacategory

To meet the third research objective, participants behaviours were evaluated in the context of the specific influences of Industry 4.0 adoption. The literature review had highlighted that leaders that are pursuing innovation-based change would benefit from ambidextrous strategies that aimed to create value from knowledge. Knowledge based value could be derived from applying existing knowledge in a new way, which would be an exploitative strategy or knowledge-based value could be derived from proprietary, novel ideas, which would be an exploratory strategy.

The study data supports this proposition; the participants were predominantly concerned with data identification, collection, management, integration, and interpretation using Industry 4.0 technologies. Their anticipated improvements were derived from the improved management of this data, to give more efficient insight and therefore knowledge within the organisation. The specific leadership behaviours changed with the amount of knowledge the participants had. The credibility of available knowledge, accessibility, and ability to diffuse knowledge throughout their organisation all affected their progress with adoption of Industry 4.0.

As a result, the behavioural taxonomy was evaluated to see how it could be structured to reflect the importance of knowledge management as a leadership behaviour. This proposed restructure reflects the importance of knowledge management within the organisation, as it removes the solely external focus. Facilitating collective learning is viewed as more closely aligned with knowledge management than change based behaviours, and so this behavioural subcomponent has been moved. By highlighting the leadership behaviours relevant to knowledge management, this restructure also positions the taxonomy closer to the body of knowledge on innovation and strategy, providing a foundation reference point for more integrated research in the future. The proposed structure is highlighted in the table below.

Meta Category and Aim	Behavioural Subcomponent	Subcomponent Definition and Aim
Task Based Behaviours: 'Define the group or organisational objectives and to ensure that people, equipment, and other resources are used in an efficient way to accomplish the mission of a group or organisation' (Yukl, 2012, p. 69)	Clarifying	'ensure that the plan will meet group or organisational objectives and that people understand what to do, how to do it, and the expected results'
	Monitoring	'monitoring involves gathering information about the operations of the manager's organisational unit, including the progress of the work, the performance of individual subordinates, the quality of products and services, and the success of projects or programs'. (Yukl, 2012, p. 70)
	Planning	'cognitive effort required to identify and plan the scope and execution required to support organisational activities.' (Yukl, 2012, p. 70).
	Problem Solving	address the 'disruption of normal operations and member behaviour that is destructive, illegal or unsafe' (Yukl, 2012, p. 70)
Relations-based behaviours: 'to enhance member skills, the leader-member relationship, identification with the work unit or organisation and commitment to the mission' (Yukl, 2012, p. 71)	Developing	'increase the competencies of all members of the organisation and support the development of roles and responsibilities that match the needs of the organisation'
	Supporting	'showing positive regard, building cooperative relationships, and helping people cope with stressful situations' (Yukl, 2012, p. 71)
	Recognising	'providing praise and recognition for effective performance, significant achievements, special contributions, and performance improvements' (Yukl, 2012, p. 72)
	Empowering	'giving subordinates more autonomy and influence over decisions about the work' (Yukl, 2012, p. 72)
	Mission Matching	'demonstrating alignment to organisational values through transparent decision and evaluation processes'
Change based behaviours: 'to increase innovation, collective learning and adaptation to external change' (Yukl, 2012, p. 72) .	Advocating Change	'explaining why change is urgently needed, observable examples include similar work unit or competitors have better performance, explaining credible threats and opportunities, and undesirable outcomes if they are not responded to'
	Envisioning Change	'articulating a clear, appealing vision of what can be attained by the work unit or organisation' (Yukl, 2012, p. 73)
	Encouraging Innovation	'challenging people to question their assumptions about the work and to consider better ways to do it' (Yukl, 2012, p. 73)

Knowledge based Behaviours: 'Support knowledge-based value creation within the organisation, by ensuring credible information is shared to all relevant parties in a timely manner'	Networking	'building and maintain favourable relationships with peers, superiors, and outsiders who can provide information, resources and political support. It includes relationship building tactics such as finding common interests' (Yukl, 2012, p. 75).
	External Monitoring	'analyzing information about events, trends, and changes in the external environment to identify threats and opportunities for the organizational unit', also known as 'environmental scanning' (Yukl, 2012, p. 75)
	Representing	'Represent their team or organisation in transactions with superiors, peers and outsiders such as clients and suppliers.' (Yukl, 2012, p. 75).
	Critical Evaluation	'Evaluating sources of knowledge and information networks for credibility and value'
	Facilitating Collective Learning	'integrating new knowledge to encourage improvement of current strategies and work methods (exploitation) or discovery of new ones (exploration)' (Yukl, 2012, p. 74)

Table 8 Overall Summary of Behavioural Findings

Industry 4.0 Enablers and Barriers

The study data was evaluated against enablers and barriers that were identified in the literature. The key areas that were identified in the literature were: lack of clarity on what Industry 4.0 is, the impact of exponentially evolving, interacting technologies, appropriate business models to calculate the return on investment of rapidly scalable technologies, the impact of technologies on the roles, skills and responsibilities of the workforce and the impact of the organisations' structure and culture. Data from this study provides support for all these areas as factors that can enable or hinder the adoption of Industry 4.0 technologies. The literature diverged on which factor had the biggest impact; one study posited that skills availability was the most impactful, whilst another suggested the availability of investment capital was the most impactful. Findings in this study suggest that an influencing factor does not have universal impact, but that the organisational response to the factor defines whether it is an inhibitor or enabler. Examples of the factors, and how they can have simultaneously diverging effects are summarised in the table below.

Literature Identified Factor	Examples of enabling impact	Examples of inhibiting impact
Industry 4.0 definition	Organisations setting their own definition and language as relevant to their objectives. Participants in this study prioritised the role of data.	Lack of definition inhibits identification of learning and knowledge exchange opportunities
Rate of technology development	Framing as multiple opportunities; adoption as an iterative, ambidextrous strategy	Challenge to identify appropriate initial scope of adoption
Busines Model & ROI	Available budget for pilot projects with no ROI expected	Scoping everything in initial proposal
Roles & Responsibilities	New roles created in organisation with specific I4.0 remit	Absence of coordination at cross organisational leadership level
Workforce Skills	Setting adoption pace alongside realistic upskilling plans for employees Engaging with universities that offer I4.0 targeted modules	Unwillingness to learn demonstrated by sections of employees
Organisational Structure	Flatter, less hierarchal structures Cross functional teams involved in adoption projects	One approver who must be 'convinced' to accept I4.0 proposals
Organisational Culture	'Fast failure' welcomed Clear decision criteria Cross functional approval	Unclear decision criteria Singular point of review

Table 9 Summary of Industry 4.0 Findings

In addition to the factors identified via the literature review, study data was evaluated for new dynamics that affect leader engagement with Industry 4.0 adoption efforts.

A novel finding on a potential inhibiting factor was the presence of a leader with a preferred leadership style based on relations-based behaviours. The participant who was least supportive of

Industry 4.0 adoption was the leader who most clearly based his interactions on the relational behavioural subcomponents. His perception of Industry 4.0 meant that he interpreted adoption as having the consequence of trusting machine led data interpretations, instead of analysis led by his team. This was not something that he found credible or worthy of pursuing, and so he did not engage with Industry 4.0 adoption efforts, despite some of the technologies already being present in the organisation and product offering. This finding may have a strong, direct impact on practice and so would benefit from further investigation in future studies.

The second novel finding was the level of scepticism that some participants viewed Industry 4.0 with; even the participants who were most engaged recognised the potentially misleading claims associated with key technologies from suppliers. The level of scepticism that each participant held was reflected in how strongly they demonstrated change-based behaviours, in particular advocating for change. In the absence of a centralised definition and benchmarking tool for Industry 4.0, the scepticism was based on the individual participants assessment and experience with technologies and suppliers.

A third novel finding was also connected to the absence of a centralised definition and benchmarking tool for Industry 4.0. The lack of a shared definition meant that knowledge sharing and facilitating collective learning was impeded, as there was not enough clarity on what Industry 4.0 meant to the organisation.

The fourth novel finding was the strength of impact from wider macro trends. The participants highlighted three areas in wider society that affected how they planned to implement technology. They recognised the role of workforce demographics and reflected on the way that different age generations of employees engaged with technology. The observed trend was that younger employees not only engaged at a much more intuitive level, but that they seemed to expect a much higher interaction with 'smart' technologies in the workplace. This may be viewed as adjacent to the second macro trend that was highlighted, the increased accessibility to Industry 4.0 technologies in the personal lives of employees. This was also supported by financial barriers being lowered as technologies benefited from economies of scale. The strength of impact of leaders' targeting sustainability as a way of operating the business was also a novel finding. For two of the participants, it was the driving force for their engagement, and they appeared to feel that it was a moral obligation.

The final novel finding was the role that stakeholder expectations, in particular customer expectations, impacted the prioritisation of engaging with Industry 4.0. All the participants held the perspective that organisations needed to be seen to be engaging with Industry 4.0, even if this engagement was superficial. This was to promote the reputation of the organisation in the view of existing and potential customers and investors.

Chapter Five: Thesis Conclusion

Major Findings

The primary finding from this study is the evidence of knowledge-based leadership behaviours that are being demonstrated by leaders in response to Industry 4.0. The analysis completed supports the restructuring of the hierarchal behavioural taxonomy to rename 'externally focused behaviours' as 'knowledge-based behaviours'. The goal of this meta-category is to support knowledge-based value creation within in the organisation, by ensuring credible information is shared to all relevant parties in a timely manner.

In support of knowledge-based behaviours, behavioural subcomponents were identified. Three of the supporting behavioural subcomponents were previously identified and defined by Yukl. They were networking, external monitoring and representing. However, Yukl categorised these components in support of the externally focused behavioural meta-category. This study recommends that these three components are recategorized as primarily supporting knowledge-based behaviours. Additionally, the findings lead to the additional recommendation that facilitating collective learning is moved from the relations focused meta-category to the knowledge-based behaviours metacategory, and that the definition is updated to include a focus on the integration of new knowledge into the organisation. Finally, a new behavioural subcomponent of knowledge-based behaviour was identified. The behaviour has been named 'critical evaluation' and is a behaviour that participants demonstrated prior to the acceptance of new knowledge about Industry 4.0. It had a moderating impact on the leader's engagement with Industry 4.0 change efforts which should be further evaluated. Credibility of knowledge was heavily influenced by the source; large institutions and government-backed sources were more trusted over suppliers of the technologies.

Knowledge based behaviours: The goal of this meta-category is to support knowledge-based value creation within the organisation, by ensuring credible information is shared to all relevant parties in a timely manner.	Networking	'building and maintain favourable relationships with peers, superiors, and outsiders who can provide information, resources and political support. It includes relationship building tactics such as finding common interests' (Yukl, 2012, p. 75).
	External Monitoring	'analyzing information about events, trends, and changes in the external environment to identify threats and opportunities for the organizational unit', also known as 'environmental scanning' (Yukl, 2012, p. 75)
	Representing	'Represent their team or organisation in transactions with superiors, peers and outsiders such as clients and suppliers.' (Yukl, 2012, p. 75).
	Critical Evaluation	'Evaluating sources of knowledge and information networks for credibility and value'
	Facilitating Collective Learning	'integrating new knowledge to encourage improvement of current strategies and work methods (exploitation) or discovery of new ones (exploration)' (Yukl, 2012, p. 74)

Table 10 Knowledge Based Behaviour Metacategory

The restructuring of the taxonomy and addition of the behavioural subcomponents resulted from the 'problematisation' of the assumptions underpinning the research that the taxonomy integrates. Many of the research studies viewed leadership behaviours from the perspective of subordinates, and so limited the perspective available to researchers. By engaging directly with leaders, leadership behaviours can be reframed away from a dyadic perspective and a more complete view of the phenomenon can be captured.

A secondary finding is that the study data supported the enablers and challenges found in the literature. The challenges posed by the breadth and speed of Industry 4.0 were being addressed by the adoption of ambidextrous strategies and open collaboration. Organisations that had a flatter hierarchy and made use of cross functional teams believed that they were better positioned to adapt to Industry 4.0. The participants who sought out Industry 4.0 engagement wanted to see greater cross-organisational approaches, as well as a coordination role being taken by board level members of the organisation. In addition to the factors already identified in the literature, the impact of the leader's scepticism regarding Industry 4.0 was a key influence in how heavily leaders engaged with adoption efforts. Despite scepticism, the participants recognised that adoption efforts were also viewed with prestige by external stakeholders which assisted the organisation to position themselves competitively. Additionally, the lack of a clear definition of Industry 4.0 impeded leaders' efforts to facilitate collective learning within their organisation.

The third key finding is the strength of impact that wider macro trends are having on the motivation of leaders to pursue Industry 4.0. The leaders who were most engaged with Industry 4.0 were driven by their awareness of the importance of sustainability and were seeking applications that would reduce their organisation's carbon footprint. Additionally, the macro trend of an ageing UK population made the leaders aware of the need to find ways of deriving value with less human resource available.

Finally, the study found a nuance in the perspective of Industry 4.0 by leaders; instead of focusing on the specific technologies, they centred the use of data in how they conceptualised of Industry 4.0. This affected their approach to adoption as they sought out technologies that matched their data needs, rather than identifying technology to then feed data into. Therefore, the study built on proposed definitions of Industry 4.0 to reflect this perspective. The proposed definition is: Industry 4.0 is the sum of all disruptive innovations that derive value from the capture and networking of data to support organisational objectives.

Summary of Contribution to Knowledge

The contribution to knowledge is the identification of leadership behaviours that manage how knowledge is integrated into organisational functioning. The behaviours covered the identification and development of knowledge, critical evaluation of the knowledge, and integration and diffusion of the knowledge into the way the organisation operates at tactical and strategic levels.

Leadership Behaviour Contributions

Contributions to the body of knowledge on strategic leadership behaviours were made at several levels. This study identified new behaviours, proposes expanded definitions for existing behaviours to allow recognition of behaviours that are not solely directed at subordinates, and proposes a structural update to the taxonomy to reflect the presence of knowledge management behaviours. By proposing an updated leadership behavioural taxonomy, the study contributes to the body of knowledge by providing a clear link to the literature on innovation strategy and knowledge management. This provides a pathway for future research to further integrate knowledge management into leadership behaviour. The identification and definition of knowledge-based behaviours reframes leadership behaviours within knowledge management; this re-signification of the phenomenon creates deeper insight and coherence between the bodies of knowledge. This outcome reinforces the need for more diversity within leadership behaviour research methodology. The identification of new behaviours that were not knowledge based also supports integration with research that is conceptualised as a style, rather than sets of behaviours. In particular, the behaviour 'mission matching' and the impact of making transparent decisions in line with the organisational values offers an avenue for further integration with research on ethical and servant based leadership.

Industry 4.0 Contributions

In addition to this, the development of a definition of Industry 4.0 that reflects the perspectives of practitioners and is not attached to a specific technology allows future research to avoid further fragmentation and undue focus on the specific applications of Industry 4.0 technology, which has been an enduring criticism to date.

To support the future integration of new technologies into the definition, a framework for categorising the technologies based on how they interact with data was proposed. This model also connects the complexity of management and leadership to the category of technology, with simple data collection the least complex and enabling independent decisions by technology the most complex.

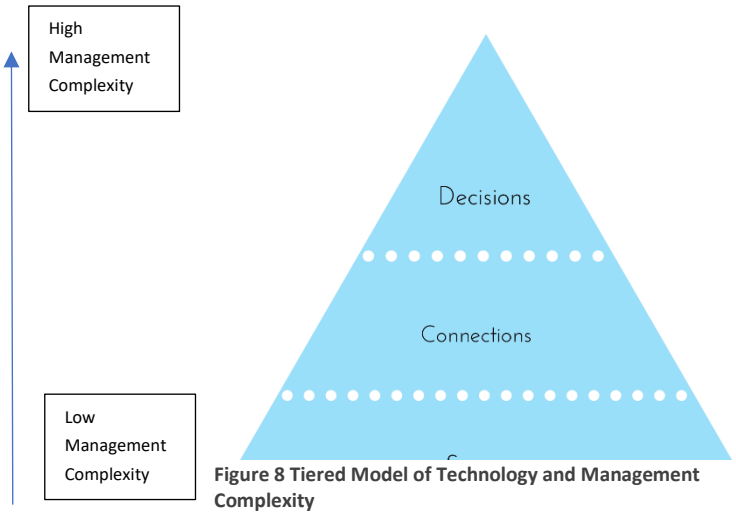

Figure 8 Tiered Model of Technology and Management Complexity

This model allows the further development of lenses to evaluate the enablers and challenges that leaders and organisations face in Industry 4.0, and how ambidextrous strategies can be formulated to manage and scale complexity in a controlled manner. In association with this, data from this study supports the findings of the enablers and challenges in the literature and further expands the knowledge of these factors and how organisations are managing them.

Methodology Contributions

A minor contribution to knowledge was made within the research methodology. The method used to recruit participants framed the participant and the researcher as customer and service provider. By framing the relationship in this way, marketing and sales knowledge was used to support recruitment efforts. This reframing of the relationship allowed the researcher to analyse their perception by the participants, and proactively use tools to enhance their credibility. This methodology may be particularly relevant to support increasing accessibility to elite participants.

Contribution to Practice

The identification of knowledge-based behaviours provides conceptual framing of adoption of Industry 4.0. This provides a lens to assess the adoption efforts through, and to identify actions that leaders can take in support of adoption. It also provides language that can be used to further increase engagement with Industry 4.0. By viewing Industry 4.0 through the lens of knowledge management, and the value that can be created from the creation and exploitation of knowledge, a deeper evaluation of adoption efforts can be made, as well as the assessment of potential technologies.

The study also provides clarity on the enablers and barriers that leaders may face and provides details of actions that practitioners can take to maximise the efficiencies of adoption.

Finally, the identification of knowledge-based behaviours could support government Industrial policy by highlighting the impact of leadership behaviour on the efficient adoption and utilisation of Industry 4.0 technologies the addition of knowledge-based behaviours provides direction for leadership development. The creation of behavioural definitions gives language to practitioners to be able to plan their response and evaluate themselves and their peers. It also defines a standard of behaviour that subordinates can access to understand the expectations of their leaders.

Contribution to Researcher's Practice

The researcher's practice has been impacted by the experience of completing this study. The study was initiated from the perspective of the researcher seeking information on how to plan their career development as a leader; and concern that a technical skills base would be required to lead within Industry 4.0.

As the researcher's understanding of the value of interpretative analysis grew, this reflected into their practice as an increased comfort with demonstrating and making explicit the values that were driving their leadership decision. They have observed their team and peers responding well to this;

feedback on their performance has highlighted that they are viewed as having strong integrity and a willingness to be vulnerable.

The review of the literature highlighted the importance of knowledge creation and sharing, internally and externally. The practitioner responding by reviewing their project structure for suitability for support knowledge flow between team members and stakeholders and initiated a new Agile based communications plan. This greatly increased the efficiency of the project team and increased the trust of the stakeholders.

The definition of the leadership behaviours has also provided a clear benchmarking tool for the researcher to assess their practice against. This has supported their planning for professional development by giving them an appropriate language to discuss development needs with their line managers. As a result of the development of their leadership behaviour, the researcher was headhunted by a competitive organisation who created a role to match the researcher. The new organisation focuses on the application of artificial intelligence in medical devices and recruited the researcher due to their ability to articulate and recognise the importance of centring data flow in the business model.

Recommendations and Implications for future research

The key limitations of this study relate to the limit of generalisability, due to the interpretative philosophy used and a smaller sample size of participants. Therefore, it is recommended that further investigations are completed in other types of organisations with a wider range of leaders.

It is also recommended that further research should focus on investigating the impact of relational leadership behaviours on the adoption of Industry 4.0. In this study, the behavioural subcomponents of recognizing and empowering were the most weakly demonstrated and this should be further investigated for validity. In addition, further research should evaluate the role of trust in Industry 4.0 adoption, as a participant raised the question of where to place their trust in Industry 4.0. The introduction of cyber-physical systems challenges a leaders' assumption of whether to place their trust in their teams or trust in the technology. The mediating role of trust within leadership effectiveness is an active area of leadership research and knowledge management, and so this study supports furthering investigations into this phenomenon (Ba Lee & Lei, 2018).

The behavioural taxonomy is limited by the lack of connection to situational variables, as well as the understanding of how demonstrating multiple behaviours in pursuit of an aim affects the effectiveness of a leader. This study did not address these limitations, as Industry 4.0 is a concept, rather than a specific situation. More explicit theories to explain the dynamics between successful innovation strategies, leadership behaviour and knowledge management are needed. Therefore, the taxonomy behaviours should be reviewed in relation to the specific paradigms of Industry 4.0 to assess if the effectiveness of specific behaviours are strengthened or weakened.

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Appendix One – Pilot Study Script

Research Setting:

Private Interview, with a camera set up as unobtrusively as possible. Water provided for participants.

Supplemental data: Prior to the interview, participants will be asked to share the results of any analysis of their behaviours that they have completed prior e.g. MBTI, Insight Colors.

Introduction

LM: First off, please let me welcome you to this interview and thank you for taking the time to talk with me today. Research isn't possible without people like you, so please accept my thanks for this. Before we get into the questions, I just wanted to run through a few things about how this session will work.

LM: The first thing that I would like to go through is the ethical protections that you have. Anything we discuss here is completely confidential; before the data is processed, it will be anonymised. Identifiable data will never be shared with anyone, and the recordings and transcripts will be stored in a protected data management system. Additionally, I would like you to know that you have the absolute right to not answer any question that you are not comfortable with, and can end the interview at any time.

LM: As part of ensuring that you are comfortable, I have prepared an informed consent form, with some supporting information about the UK data service. [present form]. Please could you read, and if you are happy to proceed, please could you sign.

[PARTICIPANT SIGNS]

LM: Great, thank you. Do you have any questions before we move on?

[ANSWER ANY QUESTIONS]

LM: Ok, so I just want to talk you through the structure and intent of this session. The intent is to generate really descriptive discussions of strategic leadership behaviours that you have observed in yourself or others, particularly as they relate to the Internet of Things. To support this, if you have any previously completed analysis of yourself that you are happy to share, please could I have a copy?

[PARTICIPANT RESPONDS]

LM: In the first section, I will ask some questions about you specifically, then in the second section we will fill in a questionnaire about technology use in your career. In the third section, I would like to know more about your thoughts on the Internet of Things, and then finally we will fill out a second questionnaire that is more specific to the usage of the Internet of Things. You can probably see that I am working with a script; this is to help ensure that the data from interviews can be compared, and the questions are a starting point for what is hopefully descriptive discussions of your observations and thoughts. Ready to start?

[PARTICIPANT CONFIRMS]

Section 1:

LM: Can you describe your current role and key responsibilities?

[PARTICIPANTS ANSWERS]

LM: Can you take me through your career development?

[PARTICIPANTS ANSWERS]

LM: Do you think that you have any key behaviours that have been pivotal for your growth? Can you describe them?

[PARTICIPANTS ANSWERS]

LM: What are your hopes for your future growth?

[PARTICIPANTS ANSWERS]

LM: That's really great. Is there anything that you would like to clarify or expand on before we move on to section 2?

[PARTICPANT RESPONDS]

LM: In section 2, we will complete this questionnaire. [Present questionnaire]. Although each question asks for a specific answer, I would like you to talk me through how you came to choose that answers, including descriptions of examples if possible.

Section 2:

Questionnaire 1:

1- Strongly Agree, 2- Agree, 3- Disagree, 4- Strongly Disagree

1) Technology is a key anchor in future strategic plans
2) Technology reduces uncertainty within my organisation
3) The organisation currently has adequate technology that is utilised effectively
4) I do not have the authority to introduce a new technology
5) I rely on technology more than I rely on my team to perform my role
6) If I introduced a new technology, I would need a third party to assist
7) Introducing a new technology that failed would be very detrimental to my career

LM: Fantastic. Is there anything that you would like to clarify or expand on before we move on to section 3?

[PARTICPANT RESPONDS]

LM: In section 3, we will talk specifically about the Internet of Things. To help ensure that we have the same idea in mind, I have proposed a definition of the Internet of Things, and some relevant terms such as Industry 4.0, that I have printed for your reference. Could you read this and let me know if this is in line with your understanding?

[PARTICIPANTS READS, CLARIFIES AND CONFIRMS]

Section 3:

LM: How did you become aware of the Internet of Things? Formal definition aside, how would you currently describe the Internet of Things?

[PARTICIPANTS ANSWERS]

LM: What do you see as the opportunities and barriers to using the Internet of Things?

[PARTICIPANTS ANSWERS]

LM: Do you currently use any Internet of Things technology that you know of, or are there any plans that you are aware of to introduce the Internet of Things in your Organisation?

[PARTICIPANTS ANSWERS]

LM: What key leadership behaviours would be needed to support Internet of Things technology in your organisation?

[PARTICIPANTS ANSWERS]

LM: That's really great. Is there anything that you would like to clarify or expand on before we move on to section 4?

LM: Section 4 is a questionnaire similar to the one we completed before, but more tailored to the Internet of Things. Please can I ask that you share your thought process and specific examples when selecting your responses?

[PARTICPANT RESPONDS]

Section 4:

Completion of questionnaire 2 with open discussion and reflection

Questionnaire 2:

1- Strongly Agree, 2- Agree, 3- Disagree, 4- Strongly Disagree

1) The IoT is a key anchor in future strategic plans
2) IoT would reduce uncertainty within my organisation
3) The organisation could use the IoT without significant change to the organisational structure and skills
4) I do not have the authority to introduce an IoT based technology
5) IoT would help me perform in my role better
6) If I introduced an IoT technology, I would need a third party to assist

7) Introducing IoT technology that failed would be very detrimental to my career

Conclusion

LM: Once again, thank you so much for taking the time to talk with me today. Before we wrap up, are there any points you would like to go back to or do you have any summary comments?

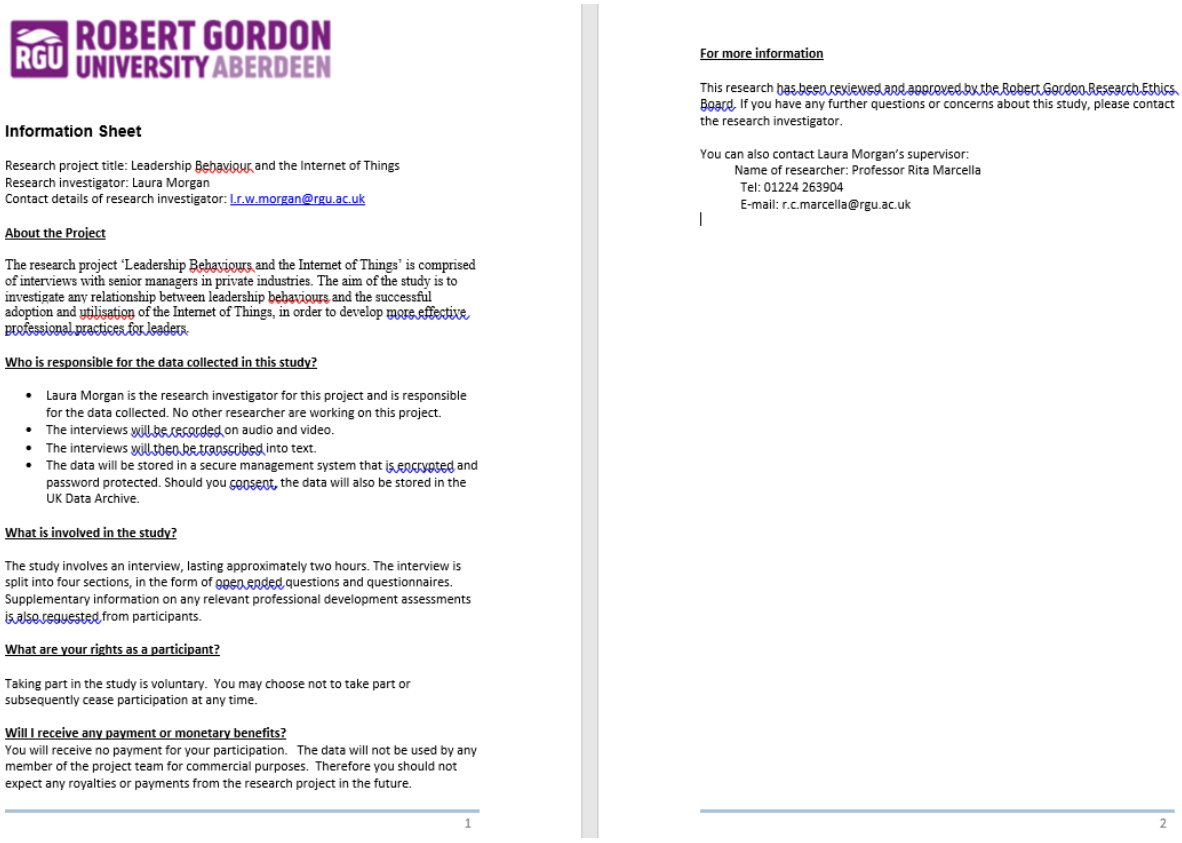
[PARTICIPANTS RESPONDS]

LM: Really insightful comments, you have been very helpful today. If you think of anything else that you would like to be considered at a later date, I will leave you with my contact details.

[LM and PARTICIPANT SAY GOODBYE]

[END OF INTERVIEW]

Appendix Two - Pilot Study Project Overview



ROBERT GORDON UNIVERSITY ABERDEEN

Information Sheet

Research project title: Leadership Behaviour and the Internet of Things
Research investigator: Laura Morgan
Contact details of research investigator: l.r.w.morgan@rgu.ac.uk

About the Project

The research project 'Leadership Behaviours and the Internet of Things' is comprised of interviews with senior managers in private industries. The aim of the study is to investigate any relationship between leadership behaviours and the successful adoption and utilisation of the Internet of Things, in order to develop more effective professional practices for leaders.

Who is responsible for the data collected in this study?

- Laura Morgan is the research investigator for this project and is responsible for the data collected. No other researcher are working on this project.
- The interviews will be recorded on audio and video.
- The interviews will then be transcribed into text.
- The data will be stored in a secure management system that is encrypted and password protected. Should you consent, the data will also be stored in the UK Data Archive.

What is involved in the study?

The study involves an interview, lasting approximately two hours. The interview is split into four sections, in the form of open ended questions and questionnaires. Supplementary information on any relevant professional development assessments is also requested from participants.

What are your rights as a participant?

Taking part in the study is voluntary. You may choose not to take part or subsequently cease participation at any time.

Will I receive any payment or monetary benefits?
You will receive no payment for your participation. The data will not be used by any member of the project team for commercial purposes. Therefore you should not expect any royalties or payments from the research project in the future.

1

For more information

This research has been reviewed and approved by the Robert Gordon Research Ethics Board. If you have any further questions or concerns about this study, please contact the research investigator.

You can also contact Laura Morgan's supervisor:
Name of researcher: Professor Rita Marcella
Tel: 01224 263904
E-mail: r.c.marcella@rgu.ac.uk

2

Appendix Three – Pilot Study Informed Consent Form

Consent Form for Strategic Leadership Behaviours and the Internet of Things

Please tick the appropriate boxes	Yes	No
Taking Part		
I have read and understood the project information sheet dated 10/08/2019.	☐	☐
I have been given the opportunity to ask questions about the project.	☐	☐
I agree to take part in the project. Taking part in the project will include being interviewed and recorded (audio and video).	☐	☐
I understand that my taking part is voluntary; I can withdraw from the study at any time and I do not have to give any reasons for why I no longer want to take part.	☐	☐
Use of the information I provide for this project only		
I understand my personal details such as phone number and address will not be revealed to people outside the project.	☐	☐
I understand that my words may be quoted in publications, reports, web pages, and other research outputs.	☐	☐
*Please choose **one** of the following two options:*		
I would like my real name used in the above	☐	
I would **not** like my real name to be used in the above.	☐	
Use of the information I provide beyond this project		
I agree for the data I provide to be archived at the UK Data Archive.	☐	☐
I understand that other authenticated researchers will have access to this data only if they agree to preserve the confidentiality of the information as requested in this form.	☐	☐
I understand that other authenticated researchers may use my words in publications, reports, web pages, and other research outputs, only if they agree to preserve the confidentiality of the information as requested in this form.	☐	☐
So we can use the information you provide legally		
I agree to assign the copyright I hold in any materials related to this project to Laura Morgan.	☐	☐

Name of participant [printed] _____ Signature _____ Date _____

Researcher [printed] _____ Signature _____ Date _____

Project contact details for further information: Names, phone, email addresses, etc.

Appendix Four – SPER Form

STUDENT PROJECT ETHICAL REVIEW (SPER) FORM

The aim of the University's *Research Ethics Policy* is to establish and promote good ethical practice in the conduct of academic research. The questionnaire is intended to enable researchers to undertake an initial self-assessment of ethical issues in their research. Ethical conduct is not primarily a matter of following fixed rules; it depends on researchers developing a considered, flexible and thoughtful practice.

The questionnaire aims to engage researchers discursively with the ethical dimensions of their work and potential ethical issues, and the main focus of any subsequent review is not to 'approve' or 'disapprove' of a project but to make sure that this process has taken place.

The *Research Ethics Policy* is available at www.rgu.ac.uk/research-ethics-policy

Student Name	**Laura Morgan**
Supervisor	**Professor Rita Marcella**
Project Title	**Strategic Leadership Behaviours and Industry 4.0**
Course of Study	**Doctorate of Business Administration**
School/Department	**Graduate School**

PART 1: DESCRIPTIVE QUESTIONS			
1.	Does the research involve, or does information in the research relate to: *[see Guidance Note 1]*	**Yes**	**No**
	(a) individual human subjects	Y	
	(b) groups (e.g. families, communities, crowds)		
	(c) organisations	Y	
	(d) animals?		
	(e) genetically-modified organisms www.rgu.ac.uk/hr/healthsafety/page.cfm?pge=26027#122628		
	Please provide further details:		
	The research involves interviewing participants to provide descriptive data regarding their own leadership behaviours, and the descriptive data is likely to reference their organisations.		

2.	Will the research deal with information which is private or confidential? *[see Guidance Note 2]*	**Yes**	**No**
			N
	Please provide further details:		
	Information that is requested does not relate to confidential or private matters.		

PART 2: THE IMPACT OF THE RESEARCH			
3.	In the process of doing the research, is there any potential for harm to be done to, or costs to be imposed on: *[see Guidance Note 3(i)]*	**Yes**	**No**
	(a) research participants?	Y	
	(b) research subjects? *[see Guidance Note 3(ii)]*		N
	(c) you, as the researcher?	Y	
	(d) third parties? *[see Guidance Note 3(iii)]*		N
	Please state what you believe are the implications of the research:		
	Potential harm to participants is unlikely to be physical; however, the process of reflecting on their own behaviour may cause an amount of anxiety or discomfort. Additionally, the time committed to an interview would not contribute to their job duties, and so the organisation may suffer a loss of productivity.		
4.	When the research is complete, could negative consequences follow:	**Yes**	**No**
	(a) for research subjects		N
	(b) or elsewhere? *[see Guidance Note 4]*		N
	Please state what you believe are the consequences of the research:		

Appendix Five – Final Research Script

Research Setting:

Private Interview in neutral business environment, with a camera set up as unobtrusively as possible. Water provided for participants.

Introduction

LM: First off, please let me welcome you to this interview and thank you for taking the time to talk with me today. Research isn't possible without people like you, so please accept my thanks for this. Before we get into the questions, I just wanted to run through a few things about how this session will work.

LM: The first thing that I would like to go through is the ethical protections that you have. Anything we discuss here is completely confidential; before the data is processed, it will be anonymised. Identifiable data will never be shared with anyone, and the recordings and transcripts will be stored in a protected data management system. Additionally, I would like you to know that you have the absolute right to not answer any question that you are not comfortable with, and can end the interview at any time.

LM: As part of ensuring that you are comfortable, I have prepared an informed consent form, with some supporting information about the UK data service. [present form]. Please could you read, and if you are happy to proceed, please could you sign.

[PARTICIPANT SIGNS]

LM: Great, thank you. Do you have any questions before we move on?

[ANSWER ANY QUESTIONS]

LM: Ok, so I just want to talk you through the structure and intent of this session. The intent is to generate descriptive discussions of strategic leadership behaviours that you have observed in yourself or others, particularly as they relate to Industry 4.0.

[PARTICIPANT RESPONDS]

LM: In the first section, I will ask some questions about you specifically, then in the second section we will fill in a questionnaire about technology use in your career. In the third section, I would like to know more about your thoughts on Industry 4.0, and then finally we will fill out a second questionnaire that is more specific to technologies in Industry 4.0. You can probably see that I am working with a script; this is to help ensure that the data from interviews can be compared, and the questions are a starting point for what is hopefully descriptive discussions of your observations and thoughts. Ready to start?

[PARTICIPANT CONFIRMS]

Section 1:

LM: Can you describe your current role and key responsibilities?

[PARTICIPANTS ANSWERS]

LM: Can you take me through your career development?

[PARTICIPANTS ANSWERS]

LM: Do you think that you have any key behaviours that have been pivotal for your growth? Can you describe them?

[PARTICIPANTS ANSWERS]

LM: What are your hopes for your future growth?

[PARTICIPANTS ANSWERS]

LM: That's really great. Is there anything that you would like to clarify or expand on before we move on to section 2?

[PARTICPANT RESPONDS]

LM: In section 2, we will complete this questionnaire. [Present questionnaire]. Although each question asks for a specific answer, I would like you to talk me through how you came to choose that answers, including descriptions of examples if possible.

Section 2:

Questionnaire 1:

2- Strongly Agree, 2- Agree, 3- Disagree, 4- Strongly Disagree

8) Technology is a key anchor in future strategic plans
9) Technology reduces uncertainty within my organisation
10) The organisation currently has adequate technology that is utilised effectively
11) I do not have the authority to introduce a new technology
12) I rely on technology more than I rely on my team to perform my role
13) If I introduced a new technology, I would need a third party to assist
14) Introducing a new technology that failed would be very detrimental to my career

LM: Fantastic. Is there anything that you would like to clarify or expand on before we move on to section 3?

[PARTICPANT RESPONDS]

LM: In section 3, we will talk specifically about Industry 4.0. To help ensure that we have the same idea in mind, I have proposed a definition of the Industry 4.o, and some relevant terms such as the

Internet of Things, that I have printed for your reference. Could you read this and let me know if this is in line with your understanding?

[PARTICIPANTS READS, CLARIFIES AND CONFIRMS]

Section 3:

LM: How did you become aware of the Industry 4.0? Formal definition aside, how would you currently describe the Industry 4.0?

[PARTICIPANTS ANSWERS]

LM: What do you see as the opportunities and barriers in Industry 4.0?

[PARTICIPANTS ANSWERS]

LM: Do you currently use any Industry 4.0 technology that you know of, or are there any plans that you are aware of to introduce the technologies in your Organisation?

[PARTICIPANTS ANSWERS]

LM: What key leadership behaviours would be needed to support Industry 4.0 technology in your organisation?

[PARTICIPANTS ANSWERS]

LM: That's really great. Is there anything that you would like to clarify or expand on before we move on to section 4?

LM: Section 4 is a questionnaire similar to the one we completed before, but more tailored to Industry 4.0. Please can I ask that you share your thought process and specific examples when selecting your responses?

[PARTICPANT RESPONDS]

Section 4:

Completion of questionnaire 2 with open discussion and reflection

Questionnaire 2:

1- Strongly Agree, 2- Agree, 3- Disagree, 4- Strongly Disagree

8) The Industry 4.0 is a key anchor in future strategic plans
9) Industry 4.0 would reduce uncertainty within my organisation
10) The organisation could use industry 4.0 technologies without significant change to the organisational structure and skills
11) I do not have the authority to introduce an Industry 4.0 based technology
12) Industry 4.0 would help me perform in my role better
13) If I introduced an Industry 4.0 technology, I would need a third party to assist
14) Introducing Industry 4.0 technology that failed would be very detrimental to my career

Conclusion

LM: Once again, thank you so much for taking the time to talk with me today. Before we wrap up, are there any points you would like to go back to or do you have any summary comments?

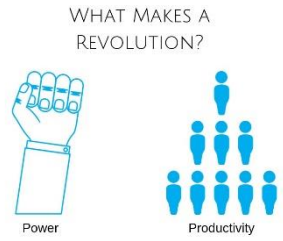
[PARTICIPANTS RESPONDS]

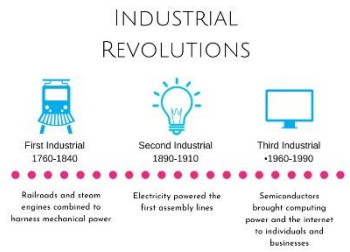
LM: Really insightful comments, you have been very helpful today. If you think of anything else that you would like to be considered at a later date, I will leave you with my contact details.

[LM and PARTICIPANT SAY GOODBYE]

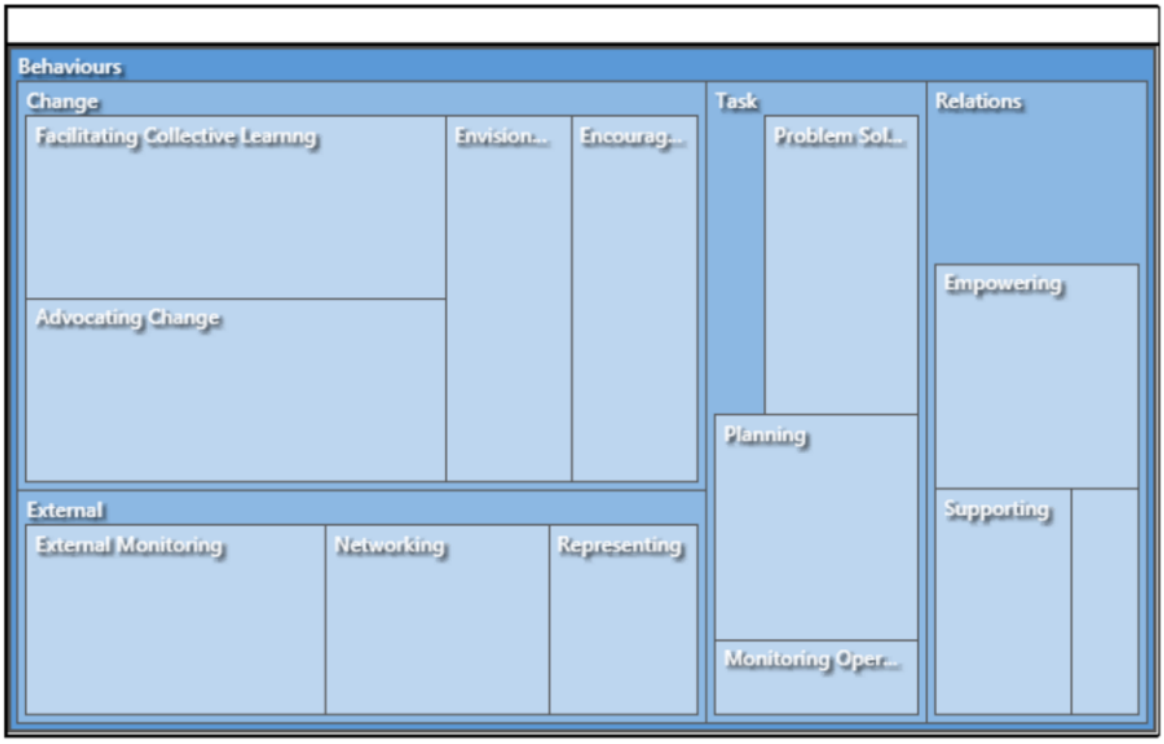
[END OF INTERVIEW]

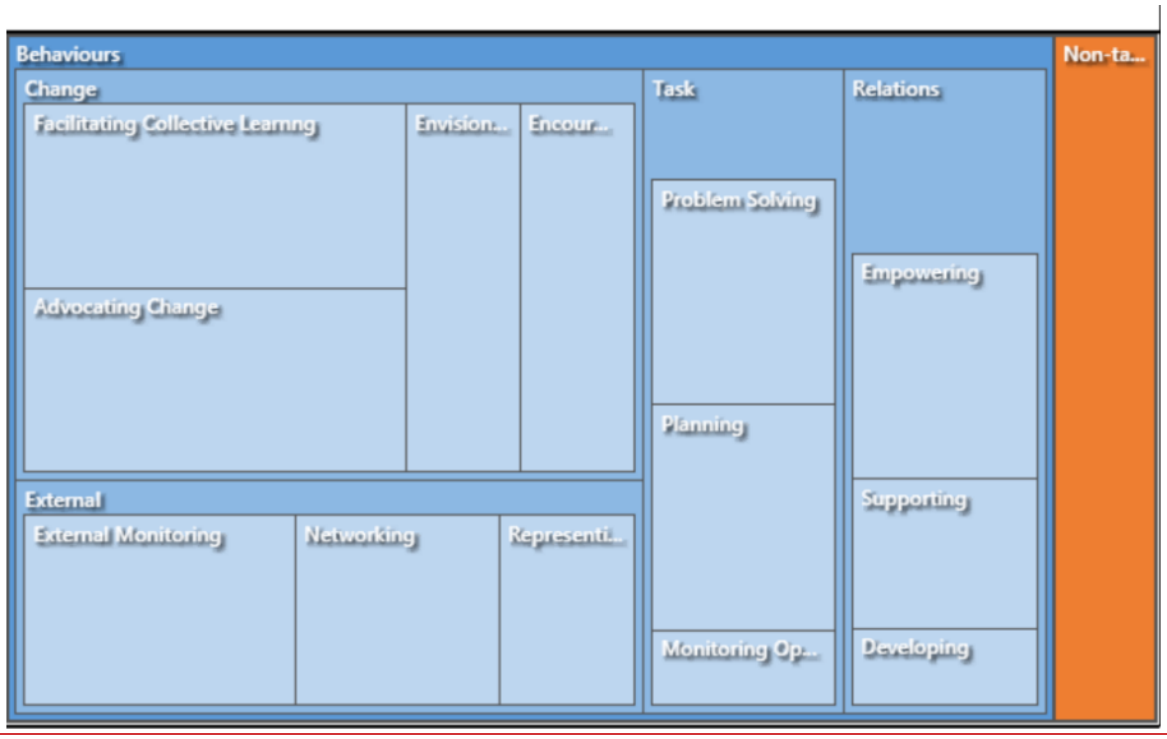
Appendix Six – Slides presented at conference

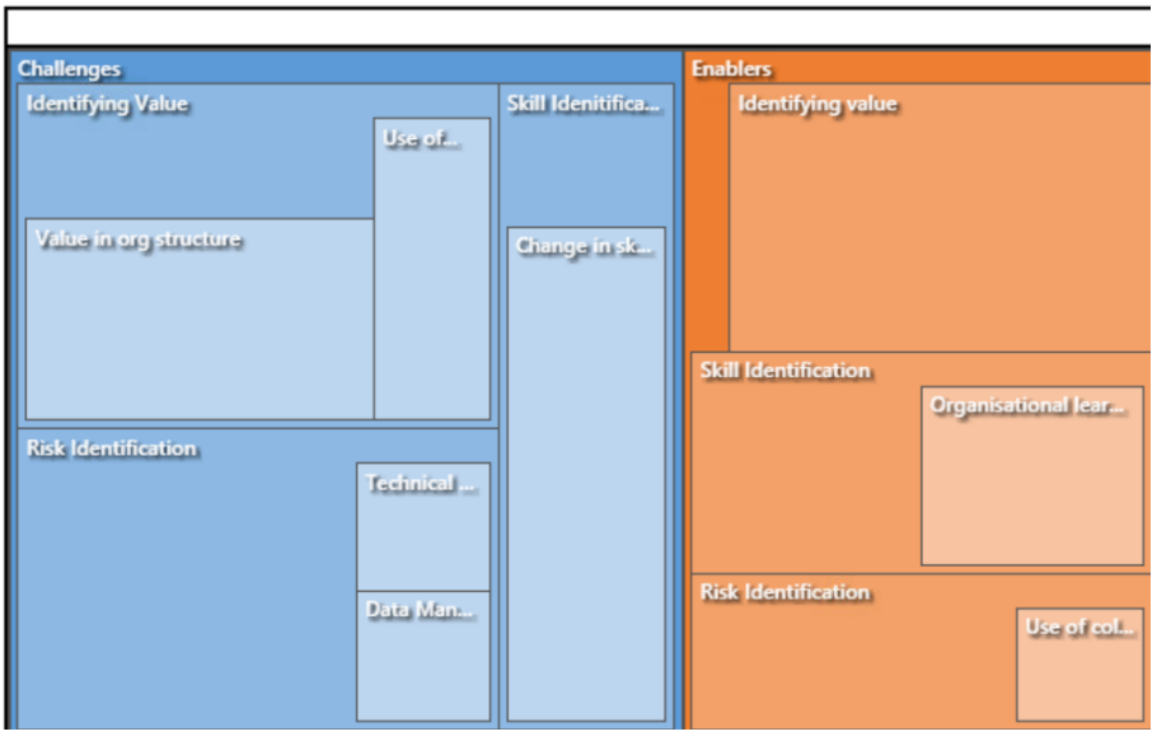




Appendix Seven – Example of Nvivo Analysis






Challenges
Identifying Value
Use of...
Value in org structure
Risk Identification
Technical ...
Data Man...
Skill Idenitifica...
Change in sk...
Enablers
Identifying value
Skill Identification
Organisational lear...
Risk Identification
Use of col...