How to develop suppliers within an Extended Enterprise towards a Digital Enterprise

A thesis submitted to the University of Cambridge for the degree of Doctor of Philosophy

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Declaration

This thesis is the result of my own work and includes nothing which is the outcome of work done in collaboration except if explicitly specified otherwise in the text.

This thesis is not substantially the same as any that I have submitted, or, is being concurrently submitted for a degree or diploma or other qualification at the University of Cambridge or any other University or similar institution. I further state that no substantial part of my thesis has already been submitted, or, is being concurrently submitted for any such degree, diploma or other qualification at the University of Cambridge or any other University or similar institution.

At the point of submission in May 2020, the thesis did not exceed the prescribed word limit for the Engineering Degree Committee. The minor corrections resulting from the viva voce in June 2020 have necessitated a small increase above 65,000 words which has been agreed by the Examiners (Professor Kulwant Pawar and Dr Mukesh Kumar).

The research was performed under a non-disclosure agreement (UTC-NDA-ETC.00864); however, this thesis has been authorised by Rolls-Royce plc for external release on an open-access basis.

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Abstract (How to develop suppliers within an Extended Enterprise towards a Digital Enterprise)

Complex supply chains span the world connecting a heterogeneous network of firms. Digitisation offers them the opportunity to improve by leveraging, for example: leaner interfirm workflows, swifter data sharing, smarter analytics and knowledge management, greater automation, and empowered decision-making. However, an onerous organisational development and change programme is required to adopt such innovations and move towards a digital enterprise.

Research into organisational change tends to be set within the confines of a single firm. Occasionally, it includes clusters of collaborating firms, but rarely does it cover the whole of an extended enterprise supply network. An exception is the supplier development process; yet, studies into its use for digitisation are very shallow. Moreover, research into the adoption and diffusion of enterprise-wide digital technologies has, to date, mostly had to consider them as piecemeal appendages. Suppliers will have choice and may be supportive, ambivalent, or outright hostile to the extent or pace of digital transformation. They may adopt different strategies in response to the investment, capability development, open access, and other such demands placed upon them by the focal firm. This 3-year longitudinal research programme studies Rolls-Royce and a tiered cross-section of 24 of its suppliers, in the aerospace sector, as they confront and embark upon the journey towards a digital enterprise.

Literature is synthesised to create a 9 step process, with 28 implementation guidelines, which is given the descriptive title of supplier development for digital transformation (SD/DT). The SD/DT process begins with a strategic review and ends by embedding practices into routine business. The guidelines are used to initiate action research cycles which coalesce around 21 workshops held at various international locations. A theoretical framework is established using a combination of institutional and organisational learning theories. Close to 100 interviews are conducted with buyers and suppliers. Furthermore, supplier scorecards capture quantitative data on a quarterly basis across the supply base. Data is triangulated between supplier outcomes and their relative absorptive capacity.

Digital minimum standards are created which provide a shared vision, common vocabulary, and framework for heterogeneous change management. Two interim waypoints are set on the journey towards a digital enterprise and progress is measured for the 24 suppliers in the cohort. Overall, an encouraging success rate is achieved. Also, the use of supplier scorecards to operationalise and measure relative absorptive capacity shows promise. There are only 3 suppliers for whom the results do not triangulate. Transferability is explored together with recommendations for further work.

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My research has studied organisational change within a global supply network over a 3-year period. The names of the suppliers and their employees have been withheld from this thesis to protect confidentiality. However, my thanks to all of the participating industrialists for being so amazingly tolerant and receptive to my application of the action research methodology to inform and influence our endeavours. At the time of writing, we are all faced with the challenges of the COVID-19 pandemic and I wish everyone well.

My academic supervision has been exemplar. As a (very) mature student, I needed a steady hand with plenty of empathy. Dr James Moultrie provided this tirelessly. Professor Tim Minshall has also been a valuable guide on my journey of discovery. On a broader scale, beyond the phenomenal support network of the University of Cambridge and the Institute for Manufacturing, my praise and thanks to several other academics who were only too willing to help from other establishments based around the world: Dr Greg Harris from Auburn University, Professor James Aitken from the University of Surrey, and Professor Du from Shanghai Jiao Tong University. Also, similar thanks and acknowledgement to the other members of my expert panel: Andy Page and Brad Farris.

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"Strive for perfection in everything. Take the best that exists and make it better. If it doesn't exist, create it. Accept nothing nearly right or good enough."

Henry Royce

"He who loves practice without theory is like the sailor who boards ship without a rudder and compass and never knows where he may cast."

Leonardo da Vinci

"If you want to truly understand something, try to change it."

Kurt Lewin

"The desire, and the ability of an organisation to continuously learn from any source – and to rapidly convert this learning into action – is its ultimate competitive advantage."

Jack Welch

"In a very real sense, there are only two roles in organisations: customers and suppliers. Everybody functions simultaneously in both roles, whether inside or outside the organisation. The essence of good business, therefore, is the quality of the relationship between customer and supplier."

Stephen Covey

"The first rule of any technology used in business is that automation applied to an efficient operation will magnify the efficiency. The second rule is that automation applied to an inefficient operation will magnify the inefficiency."

Bill Gates

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Acronyms

AL	Action Learning
APP	Application (type of software)
AR	Action Research
BNL	Business Network Learning
CAD	Computer Aided Design
CAM	Computer Aided Manufacture
CIM	Computer Integrated Manufacturing
CL	Collective Learning
CMM	Coordinate Measurement Machine
CoI	Collaborative Improvement
DMU	Digital Mock-Up
DOI	Diffusion of Innovation
DT	Digital Transformation
EDI	Electronic Data Interchange
EME	Extended Manufacturing Enterprise
ERP	Enterprise Resource Planning
I(C)T	Information (and Communication) Technology
IoT	Internet of Things
ISS	Integrated Supplier Scorecard
MBD/E	Model Based Definition/Enterprise
NPD	New Product Development
PDM	Product Data Management
PDSA	Plan-Do-Study-Act
PLM	Product Lifecycle Management
SA	Supplier Association
SCL	Supply Chain Learning
SD	Supplier Development
SD/DT	Supplier Development for Digital Transformation
SEP	Supplier Engagement Plan
SPM	Supplier Performance Management
TOE	Technology Organisation Environment

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Chapter 1

INTRODUCTION

Setting the scene

1.1   A fascinating subject to research with aspects of wickedness

My research explores organisational change where the desired future state is a Digital Enterprise and the framework for change is supplier development. Henning (1998) introduces the concept of "*The Digital Enterprise*" in her book, so titled, where she reflects upon the combined forces of digitisation, globalisation, and de-regulation. She argues:

> "*Communication and the exchange of information is at the heart of the business process whether we are designing products, negotiating deals, trading goods, promoting services or processing purchases: they constitute its very building blocks. Consequentially digitisation will affect all businesses and all sectors of the economy. Automating each and every one of these dialogues and business transactions instantly shrinks distance and accelerates the pace of the business world. But it also does more than this. It introduces different economies and opens up new innovative space. Furthermore, it creates new possibilities for alliances, opens up new markets, forces a re-assessment of organisational structure and, indeed, invites a re-appraisal of what constitutes a company's core competencies. Thus, technological change will alter not only the way we do business, but also the way we think about it.*"

A popular business process change model from the same era, shown in Figure 1.1, captures many of the important factors and considerations involved.
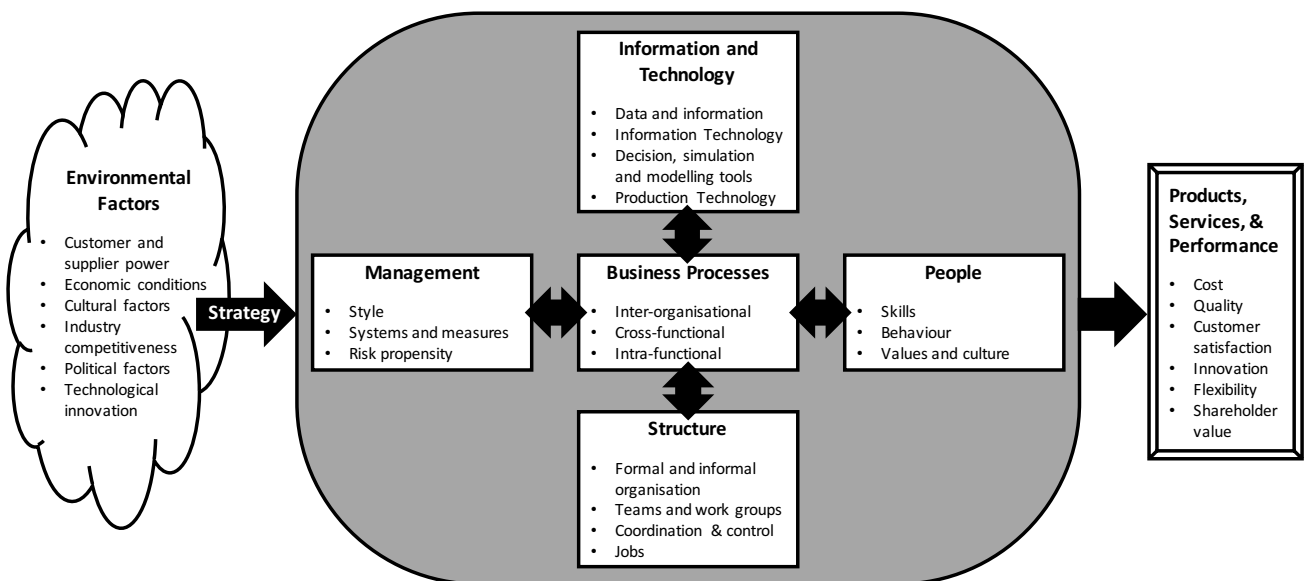
Figure 1.1:   Business process change model

(Kettinger et al, 1997)

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There have been many advances over the two decades since these articles were published; however, the Digital Enterprise is yet to become a practical reality. For the aerospace industry alone, a $190bn cumulative impact is estimated (World Economic Forum, 2017). To date, interfirm adoption and diffusion of enterprise-wide systems and tools has typically only been possible as a piecemeal digital appendage. I shall review a sample of them in chapter 2: Electronic Data Interchange (Pawar and Driva, 2000); Product Data Management (Waterson et al, 2001); Digital Mock-Up (McBeth et al, 2006); and Product Lifecycle Management (Bokinge and Malmqvist, 2012). Now, with an expansion in the capability of the tools and the digital appetite of their user base, scholars have identified a need for co-evolution and stronger alignment across the entire enterprise suite (Laframboise and Reyes, 2007; Oman et al, 2017). With this, it becomes necessary to adapt the approach to organisational change (Kohnke, 2017).

Research into organisational change tends to be set within the confines of a single firm. Occasionally, it includes clusters of collaborating firms, but rarely does it cover the whole of an extended enterprise supply network. Here, in one of the seminal articles, Chisholm (1998) lists a series of complexities which include "*organisational boundaries, budget and control systems, and pre-conceived perceptions and attitudes about other organisations*". Complex supply chains span the world connecting a heterogeneous network of firms. Digitisation offers them the potential to improve efficiency and effectiveness; however, at present, adoption and diffusion of the constituent technologies is low (Andrews et al, 2018; Ezell et al, 2018; Harris, 2018 and 2019; Guyon et al,2019). Digital maturity varies significantly, for example: hardware and legacy (brownfield) issues, software and interoperability, staff and training. Moving towards a Digital Enterprise could be very onerous.

Rittel and Webber (1973) introduce the term "*wicked problem*" and Camillus (2008) applies it to business enterprises. Leaders can be confronted with strategic issues which cannot be resolved merely by, say, gathering more data or breaking the problem down into smaller pieces. In their research into large complex systems and organisational change, Waddock et al (2015) bring together wicked problem and complexity theories to identify key characteristics and intersections. Figure 1.2 uses these to position my own research. Those which most contribute to its wickedness and complexity are: interrelated problems, systems, and institutions; and multiple stakeholder interactions. Furthermore, the problem boundary is permeable and the outcome is enigmatic.

Key characteristic (Waddock et al, 2015)	Is my circumstance wicked and complex?	Description of my research
Problem definition and boundaries	Partial	The extended enterprise comprises of multiple firms, and the supply chain is fractal, so the organisational boundaries cannot be readily determined. Also, most suppliers have more than one customer and, therefore, reside in multiple (often competing) enterprises. Furthermore, new product introduction and changing buyer/supplier relationships create permeability in the boundary of the extended enterprise. Digital technology can be emergent and disruptive.
Interrelated problems, systems, and institutions	YES	An integrated, multi-disciplinary, and holistic roadmap is desired across the extended enterprise. Digital technologies are at various levels of readiness for deployment and change is often needed in unison. However, the required investment and business case varies across the constituent firms. Also, new operating practices and business models are emerging from the digital technologies. These have the potential to impact the power regimes and working relationships between the people and the firms in the extended enterprise.
Dynamics	NO	The barriers to entry remain relatively high in the aerospace industry and the pace of change is relatively slow. Although digital technologies have the potential to be disruptive, cause-effect relationships can be determined and examined.
Resolution and outcomes	Partial	The different firms in the extended enterprise bring their own different perspectives to what constitutes a successful outcome. Furthermore, the digital technologies are themselves somewhat enigmatic. However, whilst there is no "*stopping rule*" to determine when the problem has been fully resolved, there are established metrics for the operational performance and business growth of the firms and the extended enterprise.
Predictability and patterning	NO	The impact of digital technologies on the extended enterprise does not create a chaotic system. New patterns need to be established, but more through coaching and peer pressure than through such mechanisms as "*strange attractors*".
Multiple stakeholder interactions	YES	The different stakeholders in the extended enterprise do not always (fully) agree on what is proposed or acted upon, how change should be approached, or even what the appropriate goals for change might be. However, at the same time, bringing them together is crucial to reaching a successful enterprise-wide solution. Therefore, there is a dichotomy.
Path dependency	NO	Interventions typically have reversible consequences and it should be possible to take a trial-and-error approach.

Figure 1.2: Key characteristics of my research problem

(list of key characteristics and their criteria obtained from: Waddock et al, 2015)

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1.2 Definition of key terms

Definitions of the key terms used in the three clauses which construct my research title are as follows:

1.2.1 How to develop suppliers

Supplier development (SD) is a well-established field of research. Many scholars trace it back to Leenders (1966) who conducted a case study on a Canadian manufacturer. Subsequently, according to Wagner (2006), the "*first wave*" of research began in the late 1980's with a focus upon quality management. This was followed by a "*second wave*" in the mid-1990's as researchers looked closer at business relationship issues. More recently, literature reviews point to purposes ranging from the service economy to environmental sustainability (Ahmed and Hendry, 2012; Glock et al, 2017). There is also a strong heritage in new product development and enhancing technological capabilities (e.g. Lawson et al, 2014; Krause et al, 2007; Modi and Mabert, 2006; Reed and Walsh, 2002).

Scholars broadly agree upon the underlying definition and key principles of SD. The definition provided below was synthesised by Ahmed and Hendry (2012):

> *"Any effort of a buying firm working with its supplier(s) to increase the performance and/or capabilities of the supplier and meet the buying firm's short- and/or long-term supply needs. Moreover, promotes on-going improvements that are intended to benefit both buyer and supplier(s)."*

Thus, SD can be described in terms of its context, processes, and desired outcomes. Using the framework of business relationships from Child (2001), SD is typically performed in circumstances where cooperation between firms is managed through formalised contractual provisions and improved transactional reach is required. As is the case for my research, SD may sit within an overarching framework of supplier performance and relationship management (e.g. Gordon, 2008). However, many scholars have tended to treat it as a process in its own right and there has been a propensity for weak theoretical substantiation (Sucky and Durst, 2013). Nevertheless, outcomes are consistent with supply chain learning (Bessant, 2004) and may be categorised as either operational (i.e. intended to lead to "*incremental improvements to existing ways of working*") or strategic (i.e. intended to lead to "*fundamentally different ways of doing things*"). My research is concerned with the latter.

1.2.2 Within an Extended Enterprise

Boyce (2001) reveals in his book on communicating, transferring knowledge, and learning across the corporate frontier that many such supply chain practices can be traced back to at least a century ago. However, compared to a traditional supply chain, the notion of an Extended Enterprise conveys even greater levels of collaboration and integration between firms. They are defined as follows in ISO44001 (2017):

> *"Associated entities (customers, employees, suppliers, distributors) that directly and formally or informally, collaborate in the design, development, production and delivery of a product or service to the end user. In relation to the network-orientated relationships, management of Extended Enterprises is based on a focal company view."*

The focus of my research is upon a focal firm (Rolls-Royce) and its suppliers in the aerospace industry. These firms are familiar with the organisational structure and operating principles of an Extended Enterprise. Boardman and Clegg (2001) cite a call from the Engineering Director of the focal firm in 1996 to strengthen communication and cohesion, both vertically and horizontally. At the time, the researchers used the term "*embryonic*" to describe the firm's status as an Extended Enterprise. Others, from research performed predominately in the automotive industry, have coined the term Extended Enterprise Supplier Network (Dyer, 2000) and define it as:

> *"A value chain in which the key players have created a set of collaborative processes that allow them to achieve virtual integration and work together as an integrated team."*

As a measure of scale, Rolls-Royce's enterprise resource planning (ERP) system holds over 50,000 live part numbers and executes in the order of 10 billion purchase order transactions per year. There are approaching 1000 direct suppliers. Furthermore, it is highly fractal. Taking a turbine blade, for example, there could be up to 60 chemicals required during the manufacturing process – each with their own, supplementary, supply chains. However, across the aerospace industry, there is evidence to suggest that the level of integration between firms reduces with hierarchical depth (Alfalla-Luque et al, 2013). The structure of the industry is often described as being an "*extended hierarchy*" (Thompson and McHugh, 2009) or "*tier hierarchy*" (Gadde et al, 2010). Customers are served by a relatively small number of focal firms. Contracted through them are the next tier of firms, and through them the next tier, and so forth. A highly simplified schematic of this is shown in Figure 1.3.

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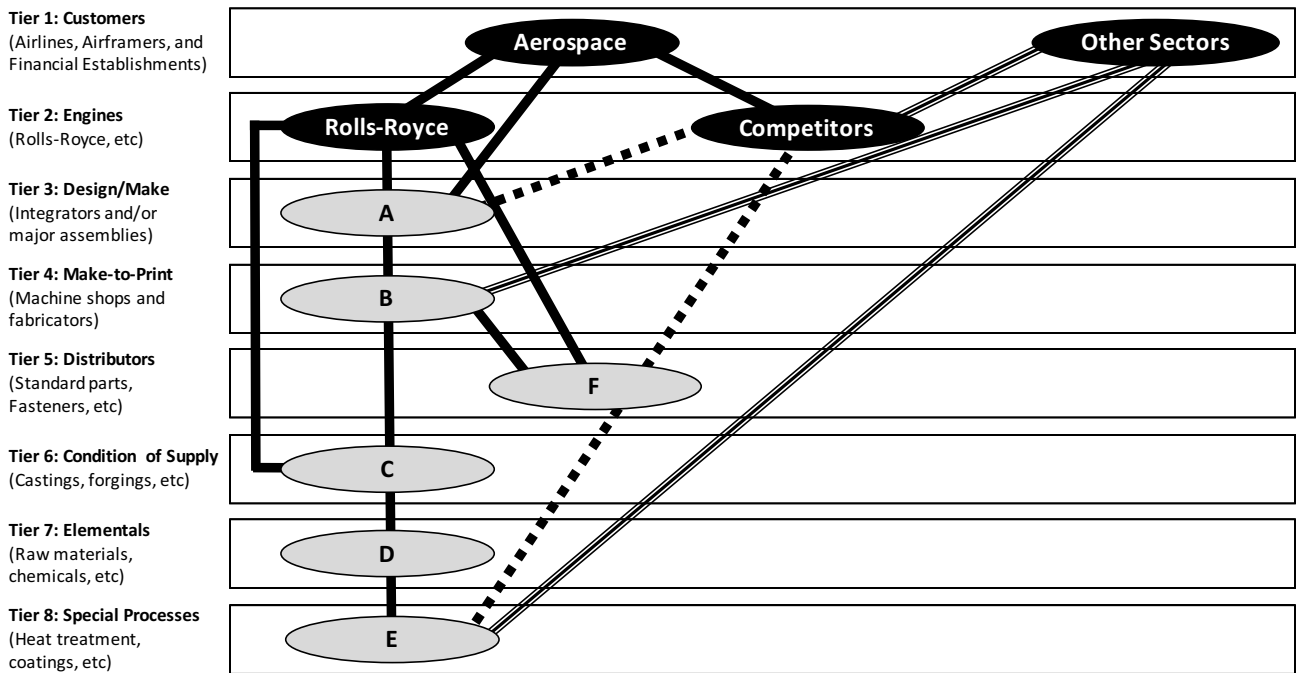
Figure 1.3: Simplified schematic of the hierarchy across the aerospace industry

Hierarchy is important to my research. Scholars, such as Otto and Obermaier (2009), reveal a strong link between hierarchy and causal power in supply networks. Also, the hierarchy is not uniform. There are other contextual factors. Gasson (2013) describes the need for "*many different disciplinary, organisational, and political interests to be negotiated and multiple, diverse, ways of working to be reconciled*" in the design of boundary-spanning systems. For illustrative purposes, using Figure 1.3, consider how some of the following contextual factors could impact power in the tier hierarchy:

a) Firms are geographically and culturally dispersed in the tier hierarchy. **A** could be a small firm headquartered in Asia; **B** could be a large firm headquartered in the USA.

b) Firms have different skills, competences, and business strategies in the tier hierarchy. **E** is shown serving a broad customer base with their technology; **F** has a much narrower focus.

c) Firms respond differently to circumstances which change over time. **D**'s technology maybe a basic commodity giving them little power; **C**'s could be a novel innovation giving them more power; but the tier-2 is intervening to consolidate orders and attempting to leverage volume.

1.2.3 Towards a Digital Enterprise

The term "*towards*" is used in my research title to denote that the target destination is emergent and progressive. A heterogeneous network of firms is involved and, therefore, careful orchestration will be required for any aspects of change which need to be performed in unison. Generically, the process of change is often referred to as digital transformation (DT). This term is defined by a professional body representing the UK aerospace industry (ATI, 2017) as: "*The accelerated evolution of business activity enabled by digital capability and technology.*"

Digital Enterprise is a more enigmatic and loosely defined term. A particularly vivid and expansive definition comes from the World Economic Forum (2016):

> "*A truly Digital Enterprise stands for more than just using new technologies for the sake of it. Rather, what truly distinguishes and gives a Digital Enterprise its competitive advantage is its culture, strategy and way of operating. Digital Enterprises strive continuously to enable new and leaner operating models underpinned by agile business processes, connected platforms, analytics and collaboration capabilities that enhance the productivity of the firm.*"

Although rare, a few scholars have used the term "*Digital Extended Enterprise*" to bridge between an Extended Enterprise and a Digital Enterprise. Laframboise and Reyes (2007) examine the supply network of an aerospace manufacturing firm and identify co-evolution of the suppliers and the enterprise systems. Various features of supply chain management became more integrated, such as: product design, manufacturing resource planning, and quality management. Pulkkinen et al (2018, 2019) develop a conceptual model for Digital Extended Enterprises which covers: strategy, organisation, processes, supply network structure, business indicators, change management, products and services, information technology, data flows and networks.

Other scholars have used the term "*Digital Supply Chain*" to convey the purpose, the technology, and the relationships. Buyukozkan and Gocer (2018) review 109 articles on the subject and I use their analysis, together with the other literature above, to capture the essence of a Digital Enterprise in Figure 1.4. This is based upon a framework of business factors (Davis and Spekman, 2004). It is an emergent continuum. Spekman and Davis (2016), for example, review progress for Extended Enterprises and highlight a paucity of research into their use of big data and predictive analytics.

Rolls-Royce c.20 years ago
e.g. Boardman & Clegg (2001)

Rolls-Royce today
The subject of my research

Business Factor From Davis and Spekman (2004)	Typical Supply Chain From Davis and Spekman (2004)	Typical Extended Enterprise From Davis and Spekman (2004)	Typical Digital Enterprise From synthesis in Section 1.2.3
Environment	Stable & static	Dynamic & changing	Emergent & disruptive
Organisational focus	Industry centric	Partnering	Agile
Approach to value-creation	Leveraging own competencies	Leveraging competencies of all members	Eco-system
Relationship Type	Teaming	Integrated	Networked
Work flows through life	Recreation & rework [paper-based]	Lean	Seamless [model-based]
Orientation	One-way workflows in series	Greater emphasis on knowledge & learning	Greater emphasis on data, analytics, and feedback loops
Decision Making	Top-down	Empowered	Rapid & reliable [More automated and/or better informed by data]
Knowledge	Predominately shared internally	Shared more widely	Smart & secure
Information Technology	Transactional	Emerging	Ubiquitous
Business Thrust	Cost-driven	Value-driven	

Figure 1.4: Essence of a Digital Enterprise

1.3   Illustrative example of a Digital Enterprise

Rolls-Royce constructed a Digital Enterprise demonstrator during my research. The initial purpose was to show how securing investment could unlock the digital future. However, I subsequently used and expanded upon it to share the vision of a Digital Enterprise more widely and to bring it more to life. The demonstrator has eleven stations and a photograph of some of them is shown in Figure 1.5. A full tour typically lasts a few hours and can be performed physically or virtually.

Figure 1.5: Digital Enterprise demonstrator

There are two stations which are overarching enablers for the Digital Enterprise: cyber-security and data analytics. There is another station which draws out and specifically focuses upon the people and cultural aspects of the Digital Enterprise: digital you. The remaining eight stations use an illustrative example to trace the business thread through the product lifecycle: starting and finishing with the customer. The demonstrator seeks to explore the value proposition with the audience and, therefore, has the customer at its core. Key to business growth and retention is high customer satisfaction which comes from delivering superior customer value (Weinstein, 2012). This is what is meant by the term "*value-driven*" in the final row of Figure 1.4. The illustrative (fictitious) example used to demonstrate the Digital Enterprise is summarised below:

a) ***Excellent customer service:*** The theme of this station is "*Imagine if we knew more about our customers than they know about themselves*". The scenario starts with fleet monitoring and identifying a potential new opportunity to delight the customer. An improvement in fuel burn is traced to a batch of components machined to one-side of the tolerance band. This is identified through 'big data' analytics which combines service and production data. The potential viability is confirmed with the customer.

b) **Automated conceptual design:** The theme of this station is "*Imagine if we could rapidly design and prove new products based on systems modelling before committing to customer requirements.*" The key takeaway for suppliers is that they can have confidence that downstream risks are analysed and reduced by Rolls-Royce before any modification programmes get launched.

c) **Accelerated closed loop detailed design:** The theme of this station is "*Imagine if product design encompassed everything we've learnt from all products across the design, manufacturing, assembly, test, and service value-streams, and from external best practice*". All of the knowledge and information comes together in one place for the design engineer. Workflows are digitally automated. The output is a model-based definition (MBD) in a paperless 3D digital format.

d) **Digital manufacturing:** The theme of this station is "*Imagine if integrated systems, combined with IoT, led to digital manufacturing insights and where our competitive advantage through right-first-time manufacturing delivered on time, to cost, every time*". The demonstrator shows the application of a range of digital capabilities. The consumption of the MBD is fully automated. The scenario passes through the industrialisation review gates and enters into full production.

e) **Supply chain excellence:** The theme of this station is "*Imagine if our supply chain were confident in our demand signal and we were confident that they could fulfil it on time, every time, to the right standard*". The demonstrator shows the integration of eSourcing, enterprise resource planning, and contract management through a Supplier Portal. The scenario explores the bull-whip effect and how inventory levels (i.e. financial cash flow) could be better optimised.

f) **Flawless assembly:** The theme of this station is "*Imagine if we provided part and build information to the point of use to improve right-first-time assembly, automated or manual, removing work content, lead-time, and cost*".

g) **Automated test:** The theme of this station is "*Imagine if we could certify a product purely based on our models and where every physical test was passed based on the cumulative digital model of actual part data*".

h) **Power as a service:** The theme of this station is "*Imagine if we are seen as service pioneers – differentiated by our reputation for enabling customers to always meet their operational goals, continuously enhancing customer experience through our service quality and value for money*".

1.4　Introduction to the researcher

I may not be the most typical of doctorial researchers; therefore, a brief introduction is in order. My research methodology can be described as being: "*work based*" (Costley et al, 2010), conducted "*in my own organisation*" (Coghlan and Brannick, 2014), and "*real world*" (Robson and McCartan, 2016).

Starting first with my key advantages: I have extensive prior knowledge and ready access to data. I have witnessed first-hand the adoption of new digital technology and its impact upon organisations. In the 1980's, I was re-trained and transitioned from drawing board to computer-aided design (CAD). I then began to explore the opportunities of CAD/CAM and working digitally with manufacturing colleagues from other firms. I now work for Rolls-Royce. I have held senior roles, including Chief Design Engineer, and worked across all phases of the product lifecycle. My current role is to provide leadership in the interface between Engineering and Procurement. I regularly visit suppliers and the outcomes of my research could have a swift and significant business impact.

My key disadvantage is that I have to take special measures to mitigate the potential for bias and any distortion of my research. My own actions may have direct impact upon my field of study and, therefore, need to be particularly well controlled and documented. I am highly aware that I may hear what I want to hear and that others may tell me what they think I want to be told. Also, there are time management and workload challenges, because I am conducting research on a part-time basis.

Hailikari et al (2007) develop a model of prior knowledge which I use in Figure 1.6 to complete my introduction. I possess prior knowledge which is both declarative and procedural across the complex and interwoven domains of my research. I have, therefore, been able to recognise facts, define meaning, understand concepts and their inter-relations, solve problems, and apply my knowledge.

	Declarative knowledge		Procedural knowledge	
Component of prior knowledge	Knowledge of facts	Knowledge of meaning	Integration of knowledge	Application of knowledge
Indicator of prior knowledge	Recognising, enumerating, recalling, remembering	Defining, reproducing, understanding	Understanding concepts and their inter-relations, classifying, comparing	Problem solving, application of knowledge, producing, implementing

Figure 1.6: Model of prior knowledge (Hailikari et al 2007)

1.5 Aim and objectives for my research

The industrial challenge set for my research was centred around digital capability acquisition, new product/process development, and organisational change for the UltraFan® engine (Rolls-Royce, 2017). The entry into service for this engine was targeted within a decade from starting my research in 2016. By then, Digital Enterprise concepts (e.g. seamless interfirm workflows in Figure 1.4) and their supporting technologies (e.g. MBD in section 1.3c/d) were forecast to have reached full maturity. This would require high-levels of knowledge transfer and diffusion across the global supply base. Hence, my research was launched by Rolls-Royce in order to respond to a gap in knowledge about Digital Enterprise organisational structures and their associated capability development.

The aim of my research is to: *Define the supplier development (SD) process for its use in an Extended Enterprise to facilitate and support organisational change towards a Digital Enterprise.* In order to fulfil this aim, the following four specific research objectives are addressed:

1) *Baselining:* Establish the generic steps in the SD process by synthesising literature from multiple sources. Derive and baseline an approach which bridges functional or domain gaps.

2) *Evolving through application:* Advance the SD process to promote and facilitate the adoption and diffusion of Digital Enterprise technologies across a complex global supply base.

3) *Embedding and sustaining:* Integrate (2) within the supplier performance management (SPM) process. Thus, establish a means to embed and sustain the journey towards a Digital Enterprise.

4) *Route proving:* Contribute to the practice of work-based research which is a relatively new field of study that is still creating and understanding methodologies (Costley et al, 2010). Thereby, also perform a route prover for Rolls-Royce who are funding the research.

Professor Ann Langley helps to put my research objectives into context with her response to the question "*Why is studying processes over time important?*" She lists four reasons (Gehman et al, 2018). Firstly, the centrality of time in our world and how much research still does not suitably take it into account. Secondly, the importance of process to practitioners. It is often the process of how to move from A to B which organisations seek to understand. Thirdly, sustainment, and the importance of process thinking to the activities and effort involved. Finally, the multiple and flowing nature of outcomes which can often otherwise be overlooked.

1.6   Overview and guide to my thesis

There are eight chapters in my thesis as summarised below:

Chapter 1: has set the scene and laid the foundations for my thesis. It describes the motivation for my research and the industrial setting. The theme is organisational change under conditions of complex heterogeneity, embedded hierarchy, and the adoption of new technology. My research aim together with four objectives are listed.

Chapter 2: provides a review of background literature to establish what is already known about supplier development (SD) for digital transformation (DT). Literature is synthesised to create a nine step process with supporting guidelines. This initial version created in chapter 2 is subsequently used to launch my fieldwork. An additional, generic, facet to the research gap is identified which supplements the need for my process to tackle the specific topic of DT. The literature review reveals that, regardless of the topic undergoing change, interfirm rivalry in the supplier network has been previously found to impede organisational learning. Therefore, my process must account for potential variability in the strategic response of firms.

Chapter 3: explains the key theories and concepts used by antecedent scholars. A theoretical framework is built for my research. Two waypoints are set on the journey towards a Digital Enterprise. At the first, supplier choice is modelled using institutional theory. At the second, diffusion and organisational adoption is modelled using institutional and organisational learning theories. Contextual factors are identified to characterise firms. One contextual factor, relative absorptive capacity, has a novel approach developed to operationalise and measure it using supplier scorecards.

Chapter 4: describes the methodological design and execution of my research. Action research is confirmed as my method and special measures are incorporated to address my complex positionality. Most notably, a steering group and expert panel are established. My action research cycles coalesce around a drumbeat of 21 group-based international workshops held over 3-years from 2017Q1 to 2020Q1. A diverse study group of 24 firms is established and their relative absorptive capacity is tracked independently. Also, buyer and supplier interviews are conducted to assess both purpose and outcomes. Success criteria for the cohort of suppliers on the SD/DT programme is developed and agreed with their buyers.

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Chapter 5: gives the first part of my empirical results in the form of a comprehensive description of the SD/DT process. This consists of nine steps for the process, twenty-eight guidelines, and four categories of special intervention. Each guideline is assessed for its criticality and the level of adherence that was achieved. Also, each category of special intervention is explained. This includes the digital minimum standards which emerged as the instrument for sharing best-practice in accordance with my theoretical framework. Encouraging signs of diffusion are provided.

Chapter 6: gives the second part of my empirical results in the form of the outcomes from the SD/DT process for the cohort of 24 suppliers. Data is compared and triangulated between the actual outcomes revealed by interviews versus those forecast by the supplier scorecards and, therein, by my proxy for relative absorptive capacity. It is shown that 18 suppliers have successful outcomes. Furthermore, it is shown that outcomes are forecast correctly by supplier scorecards for 21 suppliers. Hence, the empirical results show that my organisational change process answers the research question. It is shown to have a high success rate (18:24 suppliers) together with high potential (21:24 suppliers) to be operationalised and embedded through the supplier scorecards.

Chapter 7: discusses and explores the implications of my empirical results. Three aspects are covered. Firstly, the likely sources of measurement bias in the supplier scorecards are identified as negativity, ambiguity, and common measure. Training and the systemisation/removal of mundane transactional tasks are discussed as means of attenuating the bias. Secondly in this chapter, the perceived attributes of the digital minimum standards are reviewed and it is argued that they will continue to be perceived positively. It is explained that their baseline acceptance threshold remains unchanged for the time-being whilst diffusion grows and any issues with awareness bias are confronted and addressed. Thirdly in this chapter, my experience of work-based, part-time, research is discussed.

Chapter 8: concludes with an overall summary followed by a description of my research contribution and recommendations for further work. It is explained how I contribute to knowledge through my process for heterogeneous organisational change and my methodology for work-based research.

Figure 1.7: provides a schematic overview of my research. The full journey and my research waypoints are shown at the top together with the cohort of 24 suppliers. My organisational change process is shown centrally and, beneath it, the action research cycles used to create it.

Geographic location of firm

Relative absorptive capacity with focal firm

Size of firm

24 firms
and
7 contextual factors

Role in new product development

Power regime with focal firm

Tier in the extended enterprise

Strategic alignment with focal firm

Digital
Enterprise

Waypoint
B

Waypoint
A

Extended
Enterprise

Step 8 and 9
Grow Results and Embed into Routine Business

Step 7
Deliver Results

Step 6
Operation and Support

Step 5
Programme Launch

Step 4
Supplier Selection

Step 3
Supplier Evaluation

Step 2
Method Selection

Step 1
Strategic Review

2016 Q3
Start of
Research

2017 Q2
Selection of
Initial Cohort of Firms

2020 Q1
Twenty-first
Workshop

Major CORE
Action Research
Cycles

Minor CORE Action Research Cycles

THESIS
Action Research
Cycle

Figure 1.7: Schematic overview of my research

LITERATURE REVIEW

Establishing what is already known about supplier development (SD) for digital transformation (DT)

Chapter 1 set the scene and introduced my research aim as being to: *"Define the supplier development (SD) process for its use in an Extended Enterprise to facilitate and support organisational change towards a Digital Enterprise"*. It explained that the interfirm industrial setting for the diffusion and organisational adoption of the constituent digital technologies has complex heterogeneity and embedded hierarchy. These are potentially significant barriers to organisational learning and change.

Now, chapter 2 reviews extant literature to scope the research space and understand the research gap. This chapter is divided into six sections from 2.1 to 2.6. They begin by reviewing classic SD research and then, in section 2.3, move onto other similar and related processes. The topic to which the SD process is being considered to be applied, digital transformation (DT), is then reviewed in section 2.4. It is found that SD has only been used marginally for DT (or its antecedents) to date, but it could potentially play a much stronger and more influential role. Section 2.5 combines and consolidates the process steps and guidelines from all sections in this chapter to produce a final 'background' version for use in my fieldwork. Finally, section 2.6 summarises and draws out the key implications. A bullet-point executive summary is given overleaf for those who prefer this format.

Section 2.1: **Supplier development (SD) may be operated on a dyadic or network basis**

- SD may be conducted by firms using dyadic modes of application (direct or indirect) or through a network known as a Supplier Association (SA).

- Factors which may be used to select between these different modes of application include the desired outcomes and learning mechanisms.

Section 2.2: **SD has nine generic steps in the process**

- SD has nine generic steps in the process which are determined from a review and synthesis of extant literature.

Section 2.3: **There are other related processes which have similarities to SD**

- SD has similarities to 4 areas of organisational learning: (a) supply chain learning, (b) business network learning, (c) collective learning, and (d) action learning.

- There is a gap in organisational learning research for supplier networks (Lane, 2001). This is associated with impediments to learning which arise from factors such as interfirm competition and conflicts of interest e.g. in the aerospace sector.

- Collaborative improvement (CoI) has been studied as an alternative process to SD for interfirm learning in extended manufacturing enterprises. However, the outcomes were disappointing from three cases (aero, auto, and agricultural m/c).

Section 2.4: **SD could potentially play a strong and influential role in digital transformation (DT)**

- To date, SD has only been used marginally to influence DT (or antecedents).

- But, there are many consistent and reinforcing themes found in the SD process steps and the implementation frameworks for enterprise-wide digital systems.

- Also, it is not until recently that the functionality and readiness of digital technology has placed the concept of the Digital Enterprise within the grasp of industry. Therefore, this suggests that my research timing is favourable.

- Items for consideration from literature include: co-evolution of digital processes and the supply network, systems and data road-maps, organisational maturity models, and using a strategic framework to develop the digital supply chain.

Section 2.5: **Background SD/DT (supplier development for digital transformation) process is established to initiate my fieldwork**

- SD/DT process steps and guidelines are combined and consolidated from all of the previous sections in this chapter to produce a final 'background' version.

- This version is used later in my research to initiate my fieldwork.

Section 2.6: **Summary of research gap and key implications from this chapter**

- The research gaps which I identify and target through chapter 2 are: (i) the use of SD to facilitate DT, and (ii) organisational learning in complex supplier networks.

2.1 SD may be operated on a dyadic or network basis

Two dyadic modes of application, direct or indirect, may be taken by firms when conducting SD programmes (e.g. Glock et al, 2017; Sucky and Durst, 2013). In the case of direct SD, the buying firm invests resources into the supplier (e.g. on-site consultation, training programmes, temporary personnel transfer, or providing equipment). In the case of indirect SD, the buying firm adopts a more passive role (e.g. setting performance goals, defining improvement targets, or by offering incentives to the supplier).

Another mode of application, using a network, is credited by scholars as having evolved in the automotive industry in Japan after the Second World War. Research began to appear in the 1990's using native, anglicised, or literal terms. For example; Kyoryoku Kai (Sako, 1993), Supplier Association (Hines, 1994), and Keiretsu (Dyer, 1996). For simplicity, I will group them all together under the heading of Supplier Association (SA) which is defined as follows by Hines and Rich (1998):

> *"A mutually benefiting group of a company's most important subcontractors brought together on a regular basis in order to achieve strategic and operational alignment through the development of awareness, education and implementation programmes designed to achieve both radical and incremental improvements."*

Figure 2.1 combines research from Hines (1994) and Dyer (2000) to show the key characteristics of SA's in the automotive industry in Japan and USA. Knowledge sharing was generally found to be effective and this suggests potential for my research. However, Aitken (1998) saw mixed success from a series of case studies in the UK. He categorised four different strategies which may be adopted by the suppliers towards the SA, namely: passive, destructive, withdrawal, or constructive.

The school of SA research has been criticised by some scholars for maintaining a very simplistic view of the potential range of buyer/supplier relationships which may prevail in practice. Cox et al (2004) stereotype them as the "*lean approach to supply chain management*". They argue that buyers must typically operate in many different supply and demand circumstances compared to, for example, the long-term and non-adversarial relationships which may be possible for a few in the automotive industry.
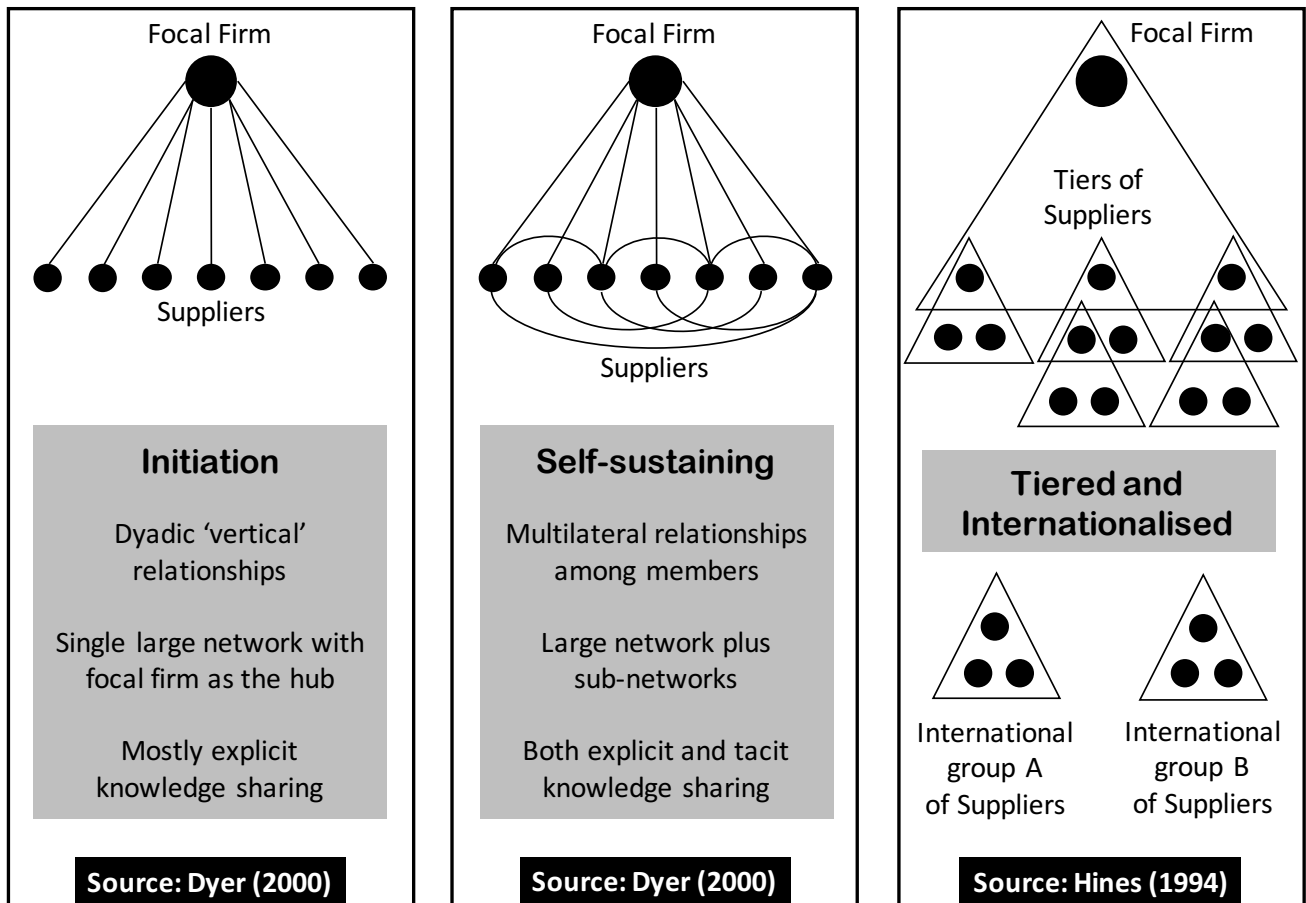
Figure 2.1: Key characteristics of automotive Supplier Associations (SA)

(See Hines and Rich, 1998, for other potential organisational structures)

Aoki and Lennerfors (2013) reflect upon the history of the SA and its contribution to improved business performance. Their assessment of Western firms concludes that the care and support of SA's has often not been sufficiently prioritised. They predict a period of reinvention and revival after cost-cutting had been the preeminent concern. They advocate the use of the SA for building deeper collaborations with suppliers, particularly at the earlier stages of product development.

Key is to not consider SD and SA in isolation. Many scholars agree that the decision if/how to create and utilise SA's must be made integral, and early, in the SD process (e.g. Krause and Handfield, 1999). Scholars also consider learning mechanisms and desired outcomes when selecting between dyadic and network modes of application (Bessant, 2004). Thus, it is prudent to review literature from both the SD and the SA schools of research in order to gain insight and guidance on the generic steps in the process. This is performed in section 2.2.

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2.2 SD has nine generic steps in the process

Despite many literature reviews into SD (e.g. Glock et al, 2017; Sillanpää et al, 2015; Sucky and Durst, 2013; Ahmed and Hendry, 2012; and Arumugam et al, 2011), they have all used simple conceptual models to characterise it and not explored the role it could play in DT. Therefore, in accordance with Tranfield et al (2003), I began by selecting articles from which to synthesise the generic steps of the process. I then used this to look at how it had, or could be, applied to DT. I sought help from an expert (Andy Page, CEO of Sharing in Growth) in order to inform and guide my selection of articles. Broader aspects of his role, and that of others, in my research is explained in Chapter 4.

A total of thirteen articles were selected as shown in Figure 2.2. The steps in the SD process which were synthesised from them are to be taken as being organised around an improvement loop. There is certainly overlap between steps and there may be iteration or repetition.

The ten articles selected for synthesis from an academic source were identified using the SCOPUS database. Searches started with the keywords "*supplier development*" or "*supplier association*", but soon expanded as the resulting articles and their references were reviewed. In accordance with my research title, shortlisting required the article to describe the "*how to*" aspects of the SD process and to be an originating source. No additional articles were identified following a final cross-check against previous SD literature reviews conducted over the last decade.

The selection of articles for synthesis from industry sources proved to be more subjective and this was where input from my independent expert was most required. Three articles were eventually selected to address the following themes. Firstly, SC21 (2006) was selected, because it describes one of the longest running SD programmes in the aerospace industry. It is important to recognise the role which may be played in SD by regional clusters and governments (Gardes et al, 2015). Secondly, SEDB (2017) was selected, because their digital maturity tool has been successfully piloted in Singapore with both small/medium enterprises and multinational corporations. It is important to recognise the impact of globalisation and the role that multinationals play in developing and sustaining indigenous firms (Liu, 2009). Finally, BCG (2017) was selected as one of the leading offerings from a consultant firm. It is important to recognise the role which they may play as either a solution shop, value-added process, or facilitated network (Christensen et al, 2013).

Figure 2.2 (table):

Generic SD Process	Hahn et al 1990	Hines 1994	Hartley & Choi 1996	Hartley & Jones 1997	Aitken 1998	Krause & Handfield 1999	Handfield et al 2000	Quayle 2000	SC21 2006	Gordon 2008	Aoki & Lennerfors 2013	SEDB 2017	BCG 2017
1 Strategic Review	Step 1	Step 1				Step 1+2	Step 1			Step 1	Guide 1	Step 1	
2 Method Selection	Step 2	Step 2+3				Step 3	Step 3	Step 1	Step 1				Phase 1
3 Supplier Evaluation	Step 3	Step 5	Step 1	Step 1	Step 1	Step 3	Step 2	Step 4	Step 2	Step 2	Guide 2	Step 2	
4 Supplier Selection		Step 4	Step 1	Step 1	Step 1	Step 4 / Step 12	Step 4	Step 2		Step 3	Guide 5		
5 Program Launch	Step 4	Step 6	Step 2	Step 2	Step 1	Step 5 / Step 12	Step 5	Step 3			Guide 3		Phase 2
6 Operation & Support		Step 7	Step 3	Step 2	Step 2+3	Step 6 / Step 7	Step 6	Step 5+6		Step 4	Guide 6	Step 3	Phase 2
7 Deliver Results	Step 5	Step 8+9	Step 4	Step 3	Step 4	Step 6 / Step 8	Step 7	Step 7	Step 3	Step 5	Guide 7		
8 Grow Results			Step 5	Step 3	Step 4	Step 9	Step 7	Step 7	Step 4		Guide 4	Step 4	Phase 3
9 Embed in Routine	Step 6	Step 10	Step 6	Step 4	Step 5	Step 10 - 12	Step 7			Step 6	Guide 8	Step 4	Phase 3

Figure 2.2: Synthesis of literature to identify nine generic process steps for SD

I broadly compared my synthesis in Figure 2.2 against the well-renowned process for leading change devised by Kotter (1995). Mine has nine steps whereas Kotter has eight; however, the sequence flows similarly and my application is more context-specific. I found no evidence of Kotter having been used where buyer/supplier relationships were a dominant factor (e.g. Auguste, 2013). Our early sequence of steps shows reasonable overlap: my steps 1 to 5, and Kotter's steps 1 to 4 (i.e. establish a sense of urgency, form a powerful guiding coalition, create a vision, and communicate the vision). Our latter sequence of steps is almost identical: my steps 6 to 9, and Kotter's steps 5 to 8 (i.e. empower others to act on the vision, plan for and create short-term wins, consolidate improvements and produce still more change, and institutionalise new approaches).

Sections 2.2.1 to 2.2.9 give the results from my synthesis. Herein, for each generic step, I capture my key findings as either a guideline or a consideration. The latter are, at this initial stage of my literature review, prompts and placeholders for when I move onto consider any other articles on digital transformation from this or other research fields.

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2.2.1 Generic process step 1: Strategic review

Most articles describe preparatory activity by the buying firm leading up to the launch of an SD/SA programme and, where they do, they refer to it as having a strongly strategic dimension. As the first generic step in the SD process, it is also essential to allow different buying firms from different starting points to anchor themselves. Krause and Handfield (1999), in particular, show multiple phases operating in series which build up through reactive, proactive, and integrated SD activities.

Guideline 1.1 – Deploy other supply base management practices ahead of SD/SA: Krause and Handfield (1999) describe the goal of rationalising the supply base to a pool of potentially capable suppliers aligned to the buyer's strategic objectives, before deploying SD/SA. Their research at the time showed the buyer's strategic goals to be dominated by a desire to improve the operational performance (i.e. quality, cost, and delivery) of a global supply base.

Guideline 1.2 – Launching and running a SD programme is not easy: Various statistics abound, but all articles give an impression that SD can be difficult and complex. Handfield et al (2000) describe SD as challenging for all parties involved, buyer and supplier, and that success is not a foregone conclusion. They list examples of the reasons for this: the commitment of financial, capital, and personnel resources; the sharing of timely and sensitive information; and the measurement and reporting of performance and progress. Furthermore, Gordon (2008) describe how the SD process can be slow, and sometimes frustrating, requiring determination, patience, and perseverance.

Guideline 1.3 – Map and include in scope the total global Extended Enterprise: In one of the later steps of their SD process, Krause and Handfield (1999) include an on-going dialogue about sub-tier suppliers. They describe the establishment of an integrated supplier network as a benchmark for organisations to strive to achieve. However, they explain that even the most advanced organisations which they studied had not achieved it in full. Furthermore, Handfield et al (2000) describe the need to "*adapt to local conditions*". There are many facets to this in a global supply chain including; language and culture, technical maturity, and the strength of the business relationship.

Consideration 1a – Operating Systems have long been an impetus for SD: In giving context to their conceptual model of the SD process, Hahn et al (1990) explain that industry in the United States had traditionally been stable and well established. However, they forecast change. When describing the key forces for change, they highlight the evolution and innovation of computer-based operating systems. They list the following examples in a matrix of SD activities where they map the development of the supplier's technical capability against their operating system: CAD/CAM, CIM/FMS, JIT/MRP. Furthermore, Krause and Handfield (1999) also cite rapid technology change as one of the drivers for SD. They list "*Global Information Systems*" as one of their five critical success factors for developing a world-class supply base. Handfield et al (2000) call for the start of the SD process to be an extension of corporate-level strategic planning and they include the participation from Information Technology (IT) in their requirements.

Consideration 1b – Disruptive technologies change the paradigm: Hartley and Choi (1996) consider the implications of major technological shifts on the incumbent supply base. Future sourcing and development is not guaranteed, even if performing well today. Handfield et al (2000) explain the need for the buying firm to first establish its long-term supply chain strategies. Krause and Handfield (1999) call for cross-functional executive input at the start of the SD process and, amongst other things, they make specific reference to technology roadmaps. Quayle (2000) refers to the coming of the "*information age*" and explains how paperless transactions offer the potential of better inter-organisational workflows. Also, as an example of one of the reasons why SD might be initiated, he lists the need to work with small and medium enterprises to be assured of "*year 2000 compliance*". Gordon (2008) gives four examples to illustrate the impetus for SD. She includes therein the buying firm seeking to implement a high-performance business system such as "*lean enterprise*" (section 2.2.10 point #1). BCG (2017) identify that both lean management and Industry 4.0 support the objectives of operational excellence, but each typically applies different types of tools to achieve these goals. In response, they update their offering to develop an integrated approach. Note that here the concept of Industry 4.0 refers to the "*fourth industrial revolution triggered by the internet which allows communication between humans as well as machines in Cyber-Physical-Systems (CPS) throughout large networks*" (Brettel et al, 2014).

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2.2.2 Generic process step 2: Selection of method and team

Handfield et al (2000) is the only article to explicitly reverse this and the next step of the process. However, they combine aspects of the first step and, therefore, have no need to show it as another discrete step at this stage of the process.

Guideline 2.1 – An informed decision is required on if/when to form an SA: Potential problems which the articles list as inputs to the decision-making process, include: setting unrealistic expectations for the suppliers, maintenance and sustainment of the SA over the longer-term, trust and openness, clarity of communication, cross-functional support, and establishing mutual benefits and sharing success across all parties. According to Hines (1994), a range of other supplier coordination and development tools are available and he explicitly lists: meetings, conferences, consultations, audits, and documented instructions. Krause and Handfield (1999) give a few examples of SA's; but, they recommend them towards the end of their SD process. They scope them as one of the most advanced strategies to be deployed at a time when the buying firm has fully prepared the ground, and is ready to establish a truly globalised supply base.

Guideline 2.2 – Top management support and a cross-functional team are essential: All articles emphasise the importance of this. Handfield et al (2000) sum it up well and describe it as "*putting your own house in order*" and then moving on to provide a "*unified front*" to the supplier. See, also, Section 2.2.10 point #2 for further input on the required roles and responsibilities for SD.

Consideration 2a – Establish a toolset and train the team: All articles comment upon the need for a cross-functional team. Some articles explicitly mention training for the team in both technical and interpersonal skills (e.g. Hines, 1994; Hartley and Jones, 1997). Aoki and Lennerfors (2013) also raise the matter of tacit knowledge and give an example of how insufficiently deep understanding is provided to a supplier through design drawings alone. An interesting example in the context of my research. Some researchers mention independent experts and coaches: SC21 (2006) offers these for what is effectively the "*lean*" toolset. The equivalent toolset for a Digital Enterprise is much less well established. However, SEDB (2017) is an early example and is described by its authors as a response to the need to create a common language and clear understanding of the key concepts in the field. It is targeted at individuals, companies, and other support partners.

2.2.3 Generic process step 3: Evaluation of suppliers

Articles begin to differ noticeably at this and the next step of the process for the sequential order in which suppliers are evaluated/selected. The difference arises because some of the articles have a relatively narrow scope (i.e. existing incumbent suppliers who are effectively already pre-selected) whereas others are looking more widely. This points strongly back to the anchoring which needs to have been achieved through the strategic review in the first generic step of the process.

Guideline 3.1 – Evaluation is likely to need to cover multiple factors: There is no noticeable change over time in the articles in their categorisation of the factors used for evaluation. Hahn et al (1990) summarise the categories as: technical, quality, delivery, cost, and managerial capability. Krause and Handfield (1999) find the supplier performance measurement systems used for this purpose to be well established across a number of the buying firms which they study.

Consideration 3a – Evaluating suppliers for digital maturity/needs will not be straight-forward: Handfield et al (2000) explain that continuous long-term improvement of supplier performance requires identifying where the value is created in the supply chain. For a Digital Enterprise, the value proposition and areas of priority and focus will need to be identified. SEDB (2017) is an example of an early response to this and their framework includes: 3 building blocks, 8 pillars, and 16 dimensions. It is described by the authors as being a deliberate attempt to address the challenges hindering Industry 4.0 adoption which arise from companies lacking a clear vision, strategy, and systematic roadmap. Gordon (2008) explains that change management skills are required at suppliers. They may benefit from using a framework such as that provided by SEDB (2017), but more data and financial insights will be required to identify and grasp the full value proposition for a Digital Enterprise.

2.2.4 Generic process step 4: Selection of suppliers

As mentioned previously for step 3, there are some differences in the articles regarding the point at which suppliers are selected. However, the way in which they describe the selection process itself is all very similar. The planned scope of subsequent activities, after selection, is all that really differs.

Guideline 4.1 – Selection criteria must be robust: The articles list many potential factors for supplier selection. They often show that a scientific analytical method is used to perform it. Factors in the selection criteria, include: the value of spend with the supplier; the strategic importance of the supplier; the alignment and closeness of the buyer/supplier relationship; the past and present operational performance of the supplier; the supplier's readiness for change; the suppliers financial position and their approach to investment; the enthusiasm of the supplier; the openness of the supplier and their management progressiveness; and the geographic location of the supplier and their proximity to either the buying firm or other suppliers being considered for participation. Gordon (2008) emphasises the need to assess whether the supplier is ready to undergo "*real change*". Krause and Handfield (1999) list three items in the criteria for selecting suppliers for their more advanced, proactive, SD activities: critical commodity, systemic history of problems, and willingness of the supplier management. They recommend maintaining strict confidentiality. The analysis and results from supplier selection should be held in private by the seniors in the buying firm.

Guideline 4.2 – Suppliers of different capability may be selected for different purposes: According to Hahn et al (1990), buying firms make a distinction in their selection of suppliers depending upon the capabilities of the supplier. The buying firm will not provide active support to them all: some suppliers will be encouraged to upgrade their own capabilities. Hartley and Jones (1997) promote the selection of suppliers with a "*good fit*" for implementing and sustaining systems-wide solutions. Krause and Handfield (1999) explain that SD can be resource intensive and should be focused accordingly. Gordon (2008) places the SD process within the framework of Supplier Performance Management (SPM) and, within this, she gives examples of the practices followed by Boeing (section 2.2.10 point #3).

Guideline 4.3 – If starting an SA, do so with a relatively small membership: Hines (1994) recommends that in the early stages, to keep activities focused and manageable, membership of a new SA should be limited to no more than 15 companies. There is no disagreement to this in any of the other articles.

Consideration 4a – NPD may be used as an alternative to SA: Aoki and Lennerfors (2013) major on the involvement and incorporation of suppliers into new product development (NPD) in their article about Toyota and the "*new, improved Keiretsu*". Krause and Handfield (1999) describe the aspirational goal for SD as being to have a globally aligned supplier network. For long term success, they also place strong emphasis on the integration of suppliers into NPD. However, in their process steps, they differentiate between phases: NPD, and then SA. Implying that the latter could be more powerful, but is more difficult to succeed.

Consideration 4b – If using an SA, constitute it to facilitate access to specialist skills: Hahn et al (1990) and Hines (1994) use a matrix to describe a broad array of capabilities and activities which may be pursued in a SD programme. Hines (1994) majors on benchmarking across suppliers and, by inference, ready access is either required to top performing suppliers or to those who are familiar with their practices.

2.2.5 Generic process step 5: Launch of programme

This process step is of a relatively short duration, but very important because it marks the formal launch event(s) for the SD/SA programme. All articles pause to reflect upon it to some degree.

Guideline 5.1 – Use the power of the voice of the customer: Hartley and Choi (1996) discuss how the involvement of the customer can be a catalyst for change. It can legitimise the change programme and help to overcome the supplier's organisational inertia. Krause and Handfield (1999) identify the significant amount of time that buyer firms spent upfront communicating their intent to top management within the supplier's organisation. Quayle (2000) recommends the use of a "*supplier conference*" to strengthen support and acceptance.

Consideration 5a – Break the stereotypes: Hartley and Choi (1996) cite one supplier manager who explains to them that to agree to participate in SD "*you have to eat your pride*". This confirms the perception that SD can become too focused upon problem areas as opposed to strategic areas of the business. Also, Gordon (2008) gives an example of a large buying firm trying to spread the message to its suppliers about a new concept which it was seeking to engage and introduce with them, called "*Lean Enterprise*". The concept was so radical and new to some of the suppliers that despite being diligent, they still only paid lip-service to it. The use of the term (i.e. Lean Enterprise) and the potential issues associated with it may have some relevance to my own research (section 2.2.10 point #1).

2.2.6 Generic process step 6: Operation and support of programme

This is an ongoing process step to cover general administration and management issues throughout the SD/SA programme, once it has been launched. With this regard, all applicable post-launch contributions from the articles are collated here.

Guideline 6.1 – There can be flexibility in the operating model: Articles describe multiple modes of delivery from part-time to full-time dedicated teams. Gordon (2008) explains how resources may come from the supplier, the customer, or third-party consultants. Although she identifies some drawbacks, she explains that the latter may be preferred should a neutral party be needed.

Guideline 6.2 – Establish change agents: Hartley and Jones (1997) note that participation from the supplier should not be limited to just a few individuals on their "*change team*" if results are to become sustained and embedded. However, should it be needed, they suggest that the buyer firm could provide support by "*shadow consulting*" rather than by hands-on assistance. Gordon (2008) argues that there is a higher risk of failure for SD activities if the supplier has little or no experience of their own in change management. Handfield et al (2000) describe the presence of a "*champion*" from within the supplier organisation. Krause and Handfield (1999) also mention the creation of "*islands of best practice*" within suppliers and how effort is required to ensure that benefits are shared by the supplier across their own sites. Beyond a single supplier, in the context of the total supply base, they go on to mention "*pockets of excellence*". They make a subtle argument for the buying firm to use these to influence others within their peer group of suppliers. Also, although they do not refer to it as such, Hartley and Choi (1996) introduce the concept of "*nudge theory*" by explaining how showcasing at an annual supplier conference can be used to stimulate interest in participation from across competing suppliers. Overall, the theme of change management is consistent and strong amongst the researchers. See section 2.2.10 point #2.

Guideline 6.3 – Principles and project charters help with communication and engagement: Hines (1994) lists a whole series of potential activities which include: conferences, seminars, specialist workshops, company visits, visits to exemplar companies, regular newsletters, and group social events. He suggests that progress against targets must be measured explicitly and regularly, perhaps twice yearly. Krause and Handfield (1999) also recommend swift feedback on performance. Aitken (1998) goes on to explain how consistent signals are required from the buyer. He argues that the

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expectations and required deliverables from the supplier have to be established and maintained very clearly to prevent adversely impacting performance. Handfield et al (2000) are more prescriptive than most and describe the formal agreement of roles and responsibilities, milestones, deliverables, and performance metrics. They give an example of a company which had seen benefit: "*spell it out*" rather than to work to a "*gentlemen's agreement*". However, Aoki and Lennerfors (2013) highlight how different organisations, individuals, and cultures prefer different approaches. They show that leaving some ambiguity can prevent results from being capped. It provides the incentive/vision to exceed and for the supplier to go the extra mile. They advocate striking a balance between explicit and implicit communication. Agreeing to team principles, in addition to creating project charters, may be a way of doing this. Upon joining SC21 (2006), participating companies are required to get their senior executive to sign their firm up to seven principles. As an example, one of the principles is called "*Delivering Innovation*" and it reads as follows: "*We will build on success to enable our industry to be a leader in the development of competitive value chains. We will pursue the most competitive solutions for our customers, by accessing innovation and specialist expertise. We will encourage innovation and investment of all types throughout the supply chain, achieved through providing a more trusting and open environment.*"

Consideration 6a – Promote the culture of a learning organisation: Krause and Handfield (1999) make reference to the concept of the "*learning organisation*". They acknowledge from their case studies that benefits were two-way and also came from buying firms looking inwards. They state in their article that "*asking suppliers to adopt practices and techniques that the buying firm itself has not adopted will only result in a loss of credibility.*" Hartley and Jones (1997) describe process-orientated SD and highlight, for example, that the buyer's forecasting, planning, and scheduling systems can cause problems for the supplier and should be included in scope for SD activities. Also, Gordon (2008) states that buying firms are typically responsible for their fair share of problems at the supplier. She recommends examining interfaces between the firms and reviewing the extent to which the associated processes and systems are causing problems.

Consideration 6b – Confidential or open-access? Handfield et al (2000) describe a high-technology buying firm who had made the subject of confidentiality a specific part of their SD agenda. They used Non-Disclosure and Exclusivity Agreements to respond to situations where confidentiality issues and concerns had been identified.

2.2.7 Generic process step 7: Delivery of short term results

I delineate the final generic steps in the process into: delivery of short term results (step 7), growth of results for the longer term (step 8), and embedding into routine business (step 9). Most articles cover the first of these; however, very few cover the last.

Guideline 7.1 – Diagnostics pinpoint specific focus areas and help to prioritise: Typically, the articles suggest that the evaluations conducted previously at step 3 provide valuable inputs, but are too general to focus attention. Hartley and Choi (1996) encourage the use of data to pinpoint problem areas. Hines (1994) describes the benchmarking of suppliers within an SA to identify individual priorities and also to identify common themes with other members of the group. Quayle (2000) recommends benchmarking to be performed against best-in-class suppliers but, if not practical, to be at least against best-in-country suppliers. Krause and Handfield (1999) call for an on-site "*risk assessment*" to be conducted by a cross-functional team. A consensus approach (i.e. strong buy-in from both parties; the supplier and the buyer) is emphasised in most articles, together with the setting and agreement of realistic levels of improvement.

Guideline 7.2 – Configure the approach to suit: Hartley and Jones (1997) warn against too much mindless repetition if the desired output is to build self-learning capability in the supplier for their long term sustainment of results. Gordon (2008) warn against falling victim to a "*trap of tools*". Aitken (1998) also found different approaches being followed with different levels of success. He proposes a more overt approach of tracking effectiveness over time. SEDB (2017) provides an approach to accommodate firms who have different starting points on their journey to a Digital Enterprise. Furthermore, BCG (2017) has developed their offering to provide an integrated combination of lean tools and digital technologies.

Guideline 7.3 – Use demonstrators and quick-wins: Hartley and Choi (1996) use the term "*model line*" to describe how automotive manufacturers use a portion of their production line, judged to offer the most potential, as the initial area of focus from which to demonstrate improvements. Krause and Handfield (1999) use the idiom "*learn to crawl before you learn to run*". Handfield et al (2000) provide examples of an evaluation criteria to identify launch projects which is based upon ease/benefit considerations (i.e. Boston Matrix). Furthermore, BCG (2017) propose the rapid development of a "*minimum viable solution*" which can be subsequently improved through iteration.

Consideration 7a – Encourage organic and direct involvement: Krause and Handfield (1999) give an example of a buying firm providing significant support to its suppliers to help them with their adoption of Electronic Data Interchange (EDI). The buying firm provides on-site training and also makes recommendations on hardware and software. The employees in the buying firm are encouraged to reach out and do this with all of their suppliers. Quayle (2000) also cites the provision of free computer hardware to encourage the adoption of EDI amongst small and medium enterprises.

2.2.8 Generic process step 8: Growth of results for the longer term

I delineate the final generic steps in the process into: delivery of short term results (step 7), growth of results for the longer term (step 8), and embedding into routine business (step 9). Most articles cover the first of these; however, very few cover the last.

Guideline 8.1 – SD activities may be categorised into phases and/or using a matrix: According to Hahn et al (1990), it helps to categorise potential activities in order to narrow their focus and direct their resolution into: capability (technical, manufacturing, quality, delivery, financial, or managerial) and source (product, process, or operating system). Furthermore, Krause and Handfield (1999) identify three phases of progression for the SD process; from reactive (problem solving), to proactive, and finally to integrative. None of the other articles are as explicit as these in their categorisation; however, on the whole, they consistently lack detail on what constitutes the end of the SD process and how to spot/implement it.

Guideline 8.2 – Take a system-wide approach: Hartley and Jones (1997) argue that a system-wide approach is required in order for SD to succeed. They explain how this is due to the interrelated nature of technical, managerial, and social systems. Krause and Handfield (1999) identify the skills gaps which exist and the requirement for suppliers to be coached to take a broader systems perspective.

Guideline 8.3 – Keep fresh: Hines (1994) suggests an iterative review cycle of every 6 months to reflect and refocus. He scopes this widely to cover supplier membership, active programmes of work, etc. Krause and Handfield (1999) describe a journey of progression. Aitken (1998) also warns against creating a "*talking shop*". He argues that continued inactivity can prevail; particularly if suppliers are adopting a "*passive*" strategy to their engagement and support.

Guideline 8.4 – Each supplier should own its roadmap: According to Hahn et al (1990), each supplier has a unique set of problems and is starting/progressing SD with different resources and capability levels. Many of the articles use the term "*roadmap*" to describe the sequenced plan which each supplier should "*own*" to achieve their goals and objectives.

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Consideration 8a – Share long-term strategies: Hines (1994) recommends sharing of long-term strategies to coordinate a supplier network and to build synergistic relationships. He points to sharing multilaterally by describing the different axes of communication: customer to supplier; visa-versa; and between suppliers once their common themes and synergies have become apparent. Krause and Handfield (1999) also refer to the sharing of technology roadmaps with suppliers who have been selected for new product/process development.

Consideration 8b – Create an expectations roadmap: Handfield et al (2000) list their top pitfalls for SD. They explain the need for buying firms to clearly articulate the value proposition to the supplier's top management in order to obtain and retain their commitment. They go onto describe how an "*expectations roadmap*" can help to build trust and improve alignment. A number of the other articles also touch on this challenge of bridging the gap between different corporate cultures and aspirations. Collectively, potential outcomes in buyer/supplier relationships are discussed in terms of: win/win, win/lose, win/draw, or visa-versa.

2.2.9 Generic process step 9: Embedding into routine business

This is the final generic step of the process and, unlike all previous steps, it is not well covered by any of the articles. There is an important gap in how to play the end-game. From spotting and preparing for it well in advance, through to the phasing and transition of matters into routine business.

Guideline 9.1 – Use of the carrot and stick: This aspect is covered by most articles. Hahn et al (1990) describe how the SD programme, if run properly over the long run, will result in participating suppliers qualifying for "*certified*" or "*preferred supplier*" status or, if they do not achieve the desired results, being removed from the supplier base. Hartley and Jones (1997) and Krause and Handfield (1999) discuss these and a range of other forms of incentives/rewards or warnings/penalties.

Guideline 9.2 – Build a supplier's capability to self-improve: For the long term sustainment of performance, Hartley and Jones (1997) describe process-orientated as opposed to results-orientated SD. Hahn et al (1990) use a matrix to direct SD activities towards developing future capability and flexibility. Striving to embed new practices and behaviours within the supplier is a common theme. Krause and Handfield (1999) view the outcome of a successful SD programme to be a self-reliant supplier who can initiate their own improvement projects and maintain momentum. Some of the articles touch on the hierarchical nature of the supply chain and the requirement for larger, top-level, suppliers to flow down the SD process to their sub-tiers. See section 2.2.10 point #3. Furthermore, BCG (2017) describes the final phase of their management consultancy process as "*scale*" when improvements are shared along the supply chain and plant network.

Consideration 9a – Take a holistic approach to SD by integrating within SPM: This is the missing link in most of the articles. The SD process does not sit in isolation. Some researchers make this point at the start of the SD process; but, none embrace it at the end. Gordon (2008) explains the role of the SD process within the broad framework of Supplier Performance Management (SPM). Amongst other things, she describes supplier scorecards and shows how key business drivers are used to define requirements and set performance expectations for suppliers. She includes technology as an attribute covered by supplier scorecards alongside cost, quality, and delivery performance. She cites Boeing as having used it to measure the product development capabilities of their suppliers. However, it is not clear what role, if any, this played in their SD process.

2.2.10 Collation, including the addition of other referenced literature

Figure 2.3 collates the guidelines and considerations for my subsequent research. For most entries, there is a clear line of sight to the source through sections 2.2.1 to 2.2.9. However, in a few cases, the literature review extended beyond the thirteen articles through their referenced articles and/or background reading. Therefore, to capture the full depth of my literature review, five supplementary points are included in Figure 2.3. These are explained below.

Point #1: Gordon (2008) refers to the concept of a "*Lean Enterprise*". In their publication on Lean Enterprise Value, Murman et al (2002) give an overview of the insights gained from the Lean Aerospace Initiative. From the same research school, Nightingale and Srinivasan (2011) look beyond this to what they call "*Enterprise Transformation*". Neither make any specific cross-reference to SD/SA; however, their work contributed to the synthesis of my Guideline 1.3 and Consideration 5a.

Point #2: A few of the articles (e.g. Hartley and Jones, 1997; Handfield et al, 2000) make reference to roles in the organisation to support and drive the SD/SA process. My background research drew heavily upon Beckhard and Harris (1987) who propose management structures and commitment strategies for organisational transitions. Furthermore, Kanter (1999) is very explicit about roles and responsibilities in her article about managing the extended enterprise in a globally connected world. Although she does not explicitly cover the steps in the SD/SA process, she describes in some detail the role of Network Champion and the creation of a Collaboration Resource Team. These supplementary sources contributed to the synthesis of my Guidelines 2.2 and 6.2.

Point #3: Gordon (2008) gives examples of practices followed by Boeing. My background research identified an article by Behrans (2008) where he explains the "*Lean Engagement*" model used by Boeing to configure their approach for different suppliers. If a supplier ranks high on their strategic scale and can self-improve, Boeing work with the supplier to align strategies and they focus on improving processes between their companies. By doing so, higher efficiencies can be achieved than by either company working by itself. If a supplier is strategic, but cannot self-improve, Boeing work with the supplier to identify and address the gaps that are preventing this. Finally, if a supplier is not strategic and cannot self-improve, Boeing use the services of external consultants to help the supplier reach their own self-improvement plateau. The article by Behrans (2008) contributed significantly to the synthesis of my Guidelines 4.2 and 9.2.

Point #4: Hines (1994) describes benchmarking across suppliers and how this can be used to identify gaps in performance and develop roadmaps to close the gaps. My background research looked beyond Supplier Associations, and the work of SD/SA researchers, to those in the field of Business Associations. In a recent study, there is an example of a broad alliance of companies and key stakeholders (FIDO: Fast Identity Online Alliance) who formed a Business Association to resolve a digital interoperability issue (Ronit, 2018). This article, and some of the predecessors in this field of research, contributed significantly to the synthesis of my Consideration 4b.

Point #5: Krause and Handfield (1999) refer to the concept of the "*learning organisation*" which they attribute to the work of Peter Senge. My background research drew from his publications on the fifth discipline, Senge (1990 first edition, 2006 second edition), and sustaining momentum, Senge et al (1999). Although there is no explicit reference to SD/SA, the latter publication includes a full section on diffusion and a sub-section on community of companies which have particularly strong resonance with SD/SA. Furthermore, Wenger et al (2002) build upon aspects of Senge's work in their publication on cultivating communities of practice and managing knowledge. They introduce the concept of the "*extended knowledge system*" which operates across the Extended Enterprise and includes: suppliers, distributors, customers, and a variety of other partners and communities outside of the focal firm. Again, no explicit reference to SD/SA, but a strong resonance. These supplementary sources contributed to the synthesis of my Consideration 6a.

Generic Process Step	Guidelines	Considerations for potential interventions when applying to Digital Enterprises
1. Strategic review	1.1 Deploy other supply base management practices ahead of SD/SA. 1.2 Launching and running a SD programme is not easy. 1.3 Map and include in scope the total global Extended Enterprise (see also supplementary #1 in Section 2.2.10).	1a. Operating Systems have long been an impetus for SD. 1b. Disruptive technologies change the paradigm.
2. Selection of method & team	2.1 An informed decision is required on if/when to form an SA. 2.2 Top management support and a cross-functional team are essential (see also supplementary #2 in Section 2.2.10).	2a. Establish a toolset and train the team.
3. Evaluation of suppliers	3.1 Evaluation is likely to need to cover multiple factors.	3a. Evaluating suppliers for digital maturity/needs will not be straight-forward.
4. Selection of suppliers	4.1 Selection criteria must be robust. 4.2 Suppliers of different capability may be selected for different purposes (see also supplementary #3 in Section 2.2.10). 4.3 If starting an SA, do so with a relatively small membership.	4a. NPD may be used as an alternative to SA. 4b. If using an SA, constitute it to facilitate access to specialist skills (see also supplementary #4 in Section 2.2.10).
5. Launch of programme	5.1 Use the power of the voice of the customer.	5a. Break the stereotypes (see also supplementary #1 in Section 2.3.10).
6. Operation & support of programme	6.1 There can be flexibility in the operating model. 6.2 Establish change agents (see also supplementary #2 in Section 2.2.10). 6.3 Principles and project charters help with communication and engagement.	6a. Promote the culture of a learning organisation (see also supplementary #5 in Section 2.2.10). 6b. Confidentiality or open-access?
7. Delivery of short term results	7.1 Diagnostics pinpoint specific focus areas and help to prioritise. 7.2 Configure the approach to suit. 7.3 Use demonstrators and quick-wins.	7a. Encourage organic and direct involvement.
8. Growth of results for the longer term	8.1 SD activities may be categorised into phases and/or using a matrix. 8.2 Take a system-wide approach. 8.3 Keep fresh. 8.4 Each supplier should own its roadmap	8a. Share long-term strategies. 8b. Create an expectations roadmap.
9. Embedding into routine business	9.1 Use of the carrot and the stick. 9.2 Build a supplier's capability to self-improve (see also supplementary #3 in Section 2.2.10).	9a. Take a holistic approach to SD by integrating within SPM.

Figure 2.3: Summary of SD guidelines & initial considerations for Digital Enterprise
(This is the first iteration derived only from literature on the SD process. See Figure 2.5 for the final version in Chapter 2)

2.3   There are other related processes which have similarities to SD

This section reviews literature on processes which are similar or related to SD, but which are not commonly referenced or included within that body of research. Scholars of SD have had a tendency to be somewhat insular and to be more applied than theoretically grounded (Sucky and Durst, 2013).

2.3.1 Four areas of organisational learning research have resonance with SD

Four areas of organisational learning research are of particular interest, namely: (a) supply chain learning, (b) business network learning, (c) collective learning, and (d) action learning. Here, I have used my own titles where there is no commonly agreed taxonomy. The first two areas cover literature exclusive to a business environment and inter-organisational learning: (a) covers that which is hierarchically power-based and more contractual in nature, and (b) covers that which is more relationship-based and highly collaborative in nature. The other areas cover literature which is less exclusive to a business environment, but where nevertheless groups are central to the learning process: (c) covers that which is more learning/development orientated, and (d) covers that which is more problem/solution orientated.

a) **Supply chain learning (SCL)**

The key tenants of SCL can be found in a report to the UK Department of Trade and Industry on using supply chains to transfer learning about best practice (Bessant et al, 1999). However, despite selecting six case studies in what were regarded as relatively advanced industrial sectors, Bessant (2004) subsequently found mixed results when studying the application of the process. He observed that a focal firm generally took the lead and followed nine sequential steps: (i) wake-up call at focal firm with the drivers varying by sector and location; (ii) initial adoption, internally, in response to the wake-up call; (iii) realisation that the internal changes are futile unless their supply chain also undergoes simultaneous complementary changes; (iv) rationalisation of the supply chain so that complementary changes can be more readily implemented and synchronised; (v) communication to the supply chain of the new requirements; (vi) mandating change in the supply chain; (vii) assisting first-tier suppliers; (viii) assisting first-tier's with their sub-tier's; and (ix) developing the capability to learn from suppliers and not just to teach them.

Comparing Figure 2.3 with the work of Bessant reveals many similarities between the nine-step processes for SD and SCL. Furthermore, there are no noteworthy gaps in that which has already been captured. SCL has not received much attention from other scholars, perhaps as a consequence of the mixed results reported by Bessant or its closeness to SD. Exceptions which have some relevance to my research are Loke et al (2012) and Sweeney et al (2005). In the former, they demonstrate a link between SCL and TQM (Total Quality Management) and argue that the activities of learning, re-learning and/or un-learning across the supply chain are mutually beneficial. In the latter, an emphasis is placed upon integrating solutions when sharing best practice on the development and implementation of ICT strategies for supply chains.

Branching out from the work of Bessant and SCL per se, but to draw in research which specifically covers the aerospace sector, then Alfalla-Luque et al (2013) studied supply chain integration. Although they identify that aerospace suppliers often group together in associations or clusters to tackle technical and management difficulties, they found no evidence of any specific behaviour aimed at promoting deeper integration. They reflect that aerospace suppliers recognise the need for integration, but see it more as an obligation rather than the result of any "*organisational conviction*". They predict that the growth of lean manufacturing will improve integrated behaviour. However, they caution that the spread of good practice has met with some resistance in the aerospace sector, because of fear of losing competitive advantage.

Finally, it is important to mention the work of Lane (2001) on organisational learning in supplier networks. He identified a gap in literature and argued that: "*Although work on organisational learning in hierarchies can be adapted so that it also becomes useful for the simulation and management of learning in supplier networks, important theoretical and practical problems remain.*" He pointed to the magnification of impediments in supplier networks driven by conflicts of interest and the fact that competition is often as important as collaboration.

Disappointingly the article by Lane has not been highly cited by scholars since. An exception is an article by Coghlan and Coughlan (2008) which sets the theoretical framework for CoI as an alternative to SD. This is covered in section 2.3.2.

b) **Business network learning (BNL)**

BNL is a broader domain of organisational learning research compared to SCL which places more emphasis upon the social exchange process. It is not as context-specific and, therefore, may not tackle the research gaps highlighted above by Lane (2001). Terminology varies amongst scholars; however, I settled upon BNL because it is used as the title of a book (Hakansson and Johanson, 2001) which collates research performed by the IMP (International Marketing and Purchasing) group. At the time of publication, the series editor explains that the IMP group had been studying inter-firm relationships for the preceding three decades. They describe BNL as typically occurring in three phases: (i) firms learn about one another's willingness and ability to continue doing business together; (ii) firms modify the routines that govern their production activities for mutual and synergistic benefit; and (iii) firms embrace longer-term coordination, for instance, through the development of new products or production processes. Other, less positive, outcomes are also included in scope for BNL, with the researchers explaining that "*learning in relationships does not always lead to closer relationships*".

Knight (2002) uses a framework to position extant literature on inter-organisational learning and network learning. She cross-tabulates: (i) the context of learning, with (ii) the level of the learner. From her literature review, she only finds one illustrative example, Dyer and Nobeoka (2000), where learning by the group of organisations is performed as a group and, through their interaction, the groups behaviour or cognitive structures are changed. Here, she argues that the network can be said to have learnt. This phenomenon is that which I am seeking to harness in order to move an Extended Enterprise towards a Digital Enterprise. The referenced article by Dyer and Nobeoka (2000) can be attributed to what Cox et al (2004) stereotype as the "*lean approach to supply chain management*". See section 2.1. Hence, I have categorised this domain of organisational learning research as BNL rather than SCL.

Knight and Pye (2004) go onto further explore the relationship between network change and network learning through an empirical study of the prosthetics (artificial limbs) supply network. This provides valuable theoretical insights for Chapter 3. However, the supply network which they study is simple and their research does not seek to address the more complex issues highlighted by Lane (2001). Overall, I found no additions to Figure 2.3 from my literature review of BNL.

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c) **Collective learning (CL)**

Garavan and Carbery (2012) describe CL as a dynamic and cumulative process, involving interactive mechanisms, whereby learning emerges through individual knowledge being shared, disseminated, diffused, and further developed. Thus, CL is similar to BNL; however, I have categorised them separately because scholars in each domain have generally worked in isolation from each other. The specific application of CL which my literature review found to be most relevant to my research is for the study of regional development.

Camagni (1991) was one of the first scholars to recognise the importance of CL for studying the growth of regional clusters of technology-intensive firms. Subsequently, Keeble (2000) synthesised a series of studies and concluded that: "*Europe's successful technology-based clusters are invariably characterised by active and relatively intense local networking, involving the exchange and development of new knowledge and enhanced collective learning between local firms and organisations, notwithstanding these clusters' different origins and structural characteristics.*" He identified three additional conditions. Firstly, that long term support and persistence was needed, over several decades, even under favourable external and environmental circumstances. Secondly, that benefit came from the role which larger firms played in orchestrating CL and networking through their local subsidiaries and/or their local supply base. Thirdly, the need for access to national and global innovation networks in order for local CL processes to be sustained and remain effective.

Physical and virtual modes of CL can be seen to converge through communities of practice. Cross and Israelit (2000), for example, consider this in the context of different levels of learner in the learning process. A more recent example comes from Gandhi et al (2016) who study the use of video-based technology to collect, share, and track the implementation of good agricultural practices across India, Afghanistan, Ethiopia, Ghana, Niger and Tanzania. They attribute the success of the non-profit organisation, called Digital Green, in driving improvements in productivity and well-being across the rural communities to their use of the CL process. They highlight how the facilitation of CL was enabled through their digital system.

Looking beyond the world of corporate business, some researchers have included CL within a broader framework called Collective Impact for tackling complex and large-scale social change (Kania and Kramer, 2011 and 2013). Here, they list five success factors:

Firstly, a common agenda. All participants must have a shared vision for change. One that includes a common understanding of the problem and a joint approach to solving it with agreed actions.

Secondly, a shared measurement system. Efforts remain aligned by collecting data and measuring results consistently using key indicators at the community level and across all participating organisations. They hold each other to account and learn from their successes and failures.

Thirdly, mutually reinforcing activities. Each participant undertakes activities in which they excel in a way that supports and is coordinated with the action of others.

Fourthly, continuous communication. Participants need several years of regular meetings to build up enough experience with each other to recognise and appreciate the common motivation behind their different efforts. Even the process of creating a common vocabulary takes time, and it is an essential ingredient to developing shared measurement systems.

Fifthly, a backbone support organisation. The expectation that collaboration can occur without a supporting infrastructure is one of the most frequent reasons why it fails. Coordination takes time and participating organisations rarely have any to spare, therefore, plan for it explicitly.

Insights gained from my literature review of CL are incorporated into the final update to Figure 2.3 which appears as Figure 2.5 in section 2.6. The contributions are labelled as CL #1, CL #2 and CL #3. They mostly apply to generic step 6 of the SD process (i.e. operation and support of the programme). However, they also supplement the guidelines and considerations for SA's.

d) **Action learning (AL)**

AL is the final area within organisational learning research where my literature review found some relevance between it and my research. At its core, AL involves taking action and reflecting upon the results. My reason for including it here, albeit very briefly, is because it is explicitly used by Coghlan and Coughlan (2008) to set the theoretical framework for CoI as an alternative to SD. See section 2.3.2. I found no other items of note for Figure 2.3 from my literature review of AL.

2.3.2 CoI is a potential alternative to SD devised for purposes similar to my own

Collaborative improvement (CoI) emerged towards the start of the twentieth century from an EU funded project called CO-IMPROVE. Kaltoff et al (2007) explain that the CO-IMPROVE project was launched in response to the lack of clear theories and tools to support inter-organisational learning in Extended Manufacturing Enterprises (EMEs). They noted that Information and Communication Technology (ICT) was still in its infancy; which was preventing it from bridging the functional, geographical and organisational barriers to the continuous improvement of EMEs. Furthermore, they argued that even with suitable ICT systems, learning together across companies in order to improve collaboratively is a non-trivial protracted process. Cagliano et al (2002) define CoI as follows:

> *"A purposeful inter-company interactive process that focuses on continuous incremental innovation, aimed at enhancing the EME overall operational performance. It is simultaneously concerned with bringing about change in the EMEs, developing EMEs capabilities, and generating actionable knowledge. Finally, it is an evolving systematic change process that is undertaken in a spirit of collaboration and learning."*

Cagliano (2000) argues that the overall performance of a supply network is partly the result of the interaction and integration between all the members; therefore, improvement should not only involve actions on supplier processes, but also actions on inter-company processes. Cagliano et al (2005) associated SD with the former (i.e. supplier processes) and introduced the concept of CoI to respond to the latter in the context of the EME (i.e. inter-company processes). In their study of an Italian aircraft manufacturer and four of its local suppliers over the period of May 2002 to February 2003, they conclude that, apart from complexity, trust is the main limitation of CoI at the EME level.

Kaltoff et al (2007) publish one of the main concluding articles from the CO-IMPROVE project where they compare each of the different approaches which were followed. In addition to the case of the Italian aircraft manufacturer, other studies were performed with a Danish agriculture hydraulics firm and a Dutch automotive electronics firm; together with three each of their local suppliers. All cases are of the initiation type (Figure 2.1) and cover up to 19 months of attempting to get CoI launched and operational.

The different implementation approaches to CoI are characterised by the researchers as: (a) top-down, directive, focusing upon goal alignment and assessment in order to provide a foundation for improvement before actually improving; (b) bottom-up, learning by doing, focusing initially at a practical level before moving up to strategy; and (c) laissez-faire, non-directed, with equal focus upon concept building and experience from practice. Kaltoff et al (2007) conclude their work by recommending a combination of all three approaches, if not from the beginning, then soon into the CoI process. Their critical success factors for implementation are: understanding and direction (from a); activity and learning (from b); and a genuine willingness to collaborate based upon trust and commitment (from c).

The outcomes of the CO-IMPROVE project are disappointing. At an industrial level, all three cases stagnated. No new improvement projects were started by any of the firms for at least the final 5 months of the 19 months of study. Furthermore, each had previously needed to be rejuvenated relatively shortly after launch. At an academic level, the published articles are not highly cited. The learning from each of the three cases only appears to have been synthesised retrospectively by the researchers. Also, most importantly in my opinion, the difference between the SD and CoI processes was insufficient for such a strong conceptual distinction to have been made. Had it been more evolutionary, then lessons learnt from the SD process may have made the CoI process more successful.

Nevertheless, CoI and the CO-IMPROVE project provide a few valuable insights for my research which are incorporated into the final update to Figure 2.3 which appears as Figure 2.5 in section 2.6. Their critical success factors resonate most strongly with generic step 6 of the SD process (i.e. operation and support of the programme) and are labelled as COI #1 in Figure 2.5.

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2.4   SD could potentially play a strong and influential role in DT

Having reviewed literature on the SD process in section 2.2, and on similar or related processes in section 2.3, this section now moves onto aspects relating to digital transformation (DT) and the journey towards a Digital Enterprise. It is not until recently that the functionality and readiness of digital technology has made the concept of a Digital Enterprise, as described in section 1.2.3, within the grasp of industry. Therefore, this section distinguishes between enterprise-wide digital systems which are discrete versus those which are seeking to be further integrated as per a Digital Enterprise.

2.4.1 SD for 'discrete' enterprise-wide digital systems or their antecedents

As industrial computer technology developed in the late 1980's, early indicators emerged which suggested a research link to SD. Bessant (1988), for example, highlighted that collaboration between customers and suppliers was necessary to deal with the complexity and high levels of systems integration required for the successful exploitation of CIM (Computer Integrated Manufacturing). Also, Mowery (1988) described how CAD/CAM (Computer Aided Design / Computer Aided Manufacturing) had made easier the "*spinning off*" of development and production tasks to either domestic or foreign firms. Cooper and Zmud (1990) proposed a technological diffusion approach for the implementation of information technology (IT). They developed a stage model for implementation which concluded with infusion (i.e. their vision was for IT to be used in a more comprehensive and integrated manner). They argued that political and learning models may be more useful when examining infusion, rather than rational decision models.

Few scholars of SD have studied the impact upon supplier technological capability; however, Reed and Walsh (2002) did so with two companies in the UK aerospace industry. They found little direct evidence of any impact, but an important indirect effect primarily through the strengthening of communication channels. They cited an example where both parties involved in the SD process (buyer and supplier) had been influenced in their adoption of CAD software by the partnership. Also, Hahn et al (1990) mapped supplier technical capability to their computer operating systems. They went onto conduct a survey to assess their relative importance to SD. However, the 81 respondents (16% response rate) ranked the domain in which early enterprise-wide digital systems were included as being of the lowest importance to SD (Watts and Hahn, 1993).

Recent empirical data on the application of SD is very patchy, but one of the more credible sources of research is from the Centre for Purchasing Studies (CAPS). They conducted a survey of SD activities in 2014 which received 43 responses from firms of varying sizes across multiple industrial sectors. Unfortunately, there is no indication of the response rate, but they argue that Information Technology (IT) is the attribute which is ranked as having been the least influenced by SD programmes (CAPS, 2014). This conclusion is consistent with extant literature from SD scholars which shows limited application of the process for matters relating to information/computer/digital systems. Electronic Data Interchange (EDI) has received the most attention (e.g. Krause and Handfield, 1999; Lauer, 2000); however, Laming (1993) helps to put this into perspective as follows:

> *"Developments in electronic data exchange have changed the nature of communication in industry greatly over the past decade and look set to do so further for some time to come. In the automotive industry, suppliers have been required to have on-line connections to their customers for such purposes as delivery requirements since the late 1980's. GM Europe, for example, intends to have 100% of its suppliers on EDI links for shipping schedules, actual delivery data and stock status data by 1994. Development of more technical communications – design data, etc., has been slower, due to the greater complexity of such transmission, and the problems for customer and supplier of protecting intellectual property rights (an electronic 'drawing' sent down a computer line is more vulnerable to piracy than a traditional print)."*

Therefore, given the limited insight which can be gained from SD scholars, I now turn my attention to those from other fields. The quote above from Laming suggests that the implementation of PLM (product lifecycle management) related technologies is more complex than EDI. Hence, I reviewed articles covering these technologies and compared them against the SD process steps and guidelines from Figure 2.3. The results for those which I found most informative are plotted in Figure 2.4.

My reason for selecting the articles used in Figure 2.4 is: Pawar and Driva (2000) provide the seminal, step-wise, implementation framework for EDI within a supply chain environment; Waterson et al (2001) study the implementation of a PLM related technology at Rolls-Royce; McBeth et al (2006) study the implementation of another related technology which builds upon the previous and covers the first use of virtual, extended, design teams at Airbus UK; and Bokinge and Malmqvist (2012) synthesise PLM guidelines and use them to inform a case study of a multinational firm.

SD process step (from Figure 2.3)	EDI Pawar & Driva (2000)	PDM Waterson et al (2001)	DMU McBeth et al (2006)	PLM Bokinge & Malmqvist (2012)	Details of any additional points raised by the EDI, PDM, DMU, or PLM articles missing from Figure 2.3
1. Strategic review	■			■	EDI #1: Build contingency planning and funding for technological breakthroughs into the strategic plan for change.
2. Selection of method and team	■	■	■	■	PDM #1: Set a clear remit for JAD (Joint Application Development) and USER groups throughout the implementation. PLM #1: If digitisation impacts processes, then change/improve them beforehand or provision to do it simultaneously.
3. Evaluation of suppliers	■				EDI #2: Spot-check surveys can help to highlight broader industry trends including digital interoperability.
4. Selection of suppliers					
5. Launch of programme	■		■		
6. Operation & support of programme	■	■	■	■	DMU #1: Events with all suppliers ensured that the same message was given to them all at the same time. PLM #2: Use expertise from third parties.
7. Delivery of short term results	■	■	**X**	■	DMU #2: Events with suppliers on a 1:1 basis were successful at resolving issues they encountered. PLM #3: Aim to satisfy rather than optimise (which I interpret to refer to the concept of the minimum viable product).
8. Growth of results for the longer term	■	■		■	EDI #3: Install a feedback loop which includes monitoring of any 'knock-on' cumulative effects.
9. Embedding into routine business			■		DMU #3: The standard required is captured in a matrix for aspiring suppliers to measure themselves & close any gaps.

Figure 2.4: Comparing SD process steps from Figure 2.3 with EDI and PLM research

■ = Agreement for the purposes of synthesis i.e. consistent and reinforcing recommendations

X = Disagreement or aspect requiring further investigation

EDI #1 through to PLM #3 provide a cross-reference to Figure 2.5

It can be seen from Figure 2.4 that there are many consistent and reinforcing contributions to my SD process steps. Unsurprisingly, there is little overlap shown against steps 3, 4 or 9; because the articles on digitisation relate to predominately incumbent suppliers as opposed to new supplier selection or supplier performance management. However, one item against step 7 warranted further investigation. McBeth et al (2006) reported that it was necessary for Airbus UK to establish a DMU (digital mock-up) support organisation due to "*reluctance to change by some suppliers*". Here, I contacted the lead author of the article and was able to confirm that her findings did not put into question my own approach. The DMU support organisation had been temporary and action was taken to prevent re-occurrence through that which I have captured as DMU #3 in Figure 2.4.

I found nothing further to add to Figure 2.4 from literature on the implementation of other 'discrete' enterprise-wide digital systems. For example: Mabert et al (2003), Laukkanen et al (2007), and Snider et al (2009) who studied Enterprise Resource Planning (ERP) implementation; or Wiengarten et al (2013) who studied e-business and its influence upon collaboration across buyer/supplier boundaries. Thus, I next turn to literature on more 'integrated' enterprise-wide digital systems.

2.4.2 SD for more 'integrated' digital systems (i.e. towards a Digital Enterprise)

As a relatively recent field of research, implementation studies do not yet exist to the same level of detail as those found in Figure 2.4. Therefore, here, I take a thematic approach to my literature review. The findings are summarised below together with a cross-reference which places them in Figure 2.5. This is the final version of my process steps and guidelines before commencing fieldwork.

Co-evolution (INT #1 in Figure 2.5): This is an update to the entry labelled PLM #1 in Figure 2.4 which refers to the relationship between digitisation and business processes. Laframboise and Reyes (2007) examine the potential for more extensive digitisation of an aerospace supply network. They identify a need to integrate several business processes in parallel in order to be successful. They point to the co-evolution of the digital enterprise systems together with the supply network.

Maturity model (INT #2 in Figure 2.5): This is an update to the entry labelled DMU #3 in Figure 2.4 which refers to establishing a minimum standard. Pulkkinen et al (2018, 2019) start to take this further by developing a maturity model for a Digital Extended Enterprise during their study of a company and a few of its suppliers producing machinery to handle mineral aggregates.

Systems and data roadmap (INT #3 in Figure 2.5): This is a supplementary note on technology roadmaps to the entries labelled 8a and 8.4 in Figure 2.3. In the case of Rolls-Royce and its supply chain, the scope at launch of this research (i.e. 2016/17) was limited to product technology and manufacturing technology. Some of the implementation guidelines for 'discrete' enterprise-wide digital systems pointed to expanding the scope. I captured it in the entry labelled EDI #1 in Figure 2.4. However, it is more strongly emphasised by scholars of the move towards a Digital Enterprise. Oman et al (2017), for example, study the integration of both ERP (Enterprise Resource Planning) and MES (Manufacturing Execution System) in the automotive supply chain. They establish a bi-directional exchange of data and find that when this is incorporated it offers controlled change management in the supply chain and real time decision-making. Furthermore, Guyon et al (2019) argue that there is a long and complex journey ahead to achieve this vision in the aerospace industry. This suggests the need for a more comprehensive systems/data roadmap between Rolls-Royce and its supply chain.

Strategic plan (INT #4 in Figure 2.5): This is an additional guideline for step 1 in Figure 2.3. As the complexity of enterprise systems has increased, and the desire to integrate them has grown, scholars have started to turn to the need to formulate strategy for DT. For example, Kane et al (2015), in their article about becoming a digitally mature enterprise, argue that strategy, not technology, drives DT. However, Matt et al (2015) reflect on the challenges of integrating and aligning DT strategies. They argue that DT strategy cuts across various other strategies at the same time and, therefore, warn that complex coordination efforts may be needed. Hess et al (2016) propose a set of guidelines which are based upon their research with three German media companies. They mention the need to acquire or develop new competencies. Buyukozkan and Gocer (2018) point explicitly to the need for a strategic framework for developing the digital supply chain.

2.5 Background SD/DT process is established to initiate my fieldwork

Whilst no scholars in sections 2.4.1 or 2.4.2 named SD outright as a key enabler, I contend that their work suggests that it could play a strong and influential role in developing suppliers from within an Extended Enterprise towards a Digital Enterprise. To this end, I shall refer to that which I am researching as the supplier development for digital transformation (SD/DT) process. For clarity, I have combined all of my findings from chapter 2 and then renumbered the guidelines and considerations into Figure 2.5. The origin of each entry is provided in brackets to allow it to be traced back to source. I will use this later to initiate fieldwork.

SD/DT process step	'Background' guidelines and considerations with which to initiate fieldwork
1. Strategic review	**1.i.** Strategy for DT cuts across various other strategies at the same time and, therefore, complex coordination efforts may be needed (from INT #4 in section 2.4.2 and 1.2/1a in Figure 2.3). **1.ii.** Build contingency planning and funding for technological breakthroughs into the strategic plan for change (from EDI #1 in Figure 2.4 and 1b in Figure 2.3). **1.iii.** Map and include in scope the total, global, supply base (from 1.3 in Figure 2.3). **1.iv.** Deploy other supply base management practices ahead of SD/SA (from 1.1 in Figure 2.3).
2. Selection of method and team	**2.i.** Use methodology which integrates business processes and co-evolves digital enterprise systems together with the supply base (from INT #1 in section 2.4.2 and PLM #1 in Figure 2.4). **2.ii.** Gain the support of top management, build a cross-functional team, and train the team in the methodology (from 2.2 and 2a in Figure 2.3). **2.iii.** Make an informed decision on if/when to launch Supplier Association(s) and set a clear remit for JAD (Joint Application Dev) and/or USER groups (from 2.1 Figure 2.3 & PDM #1 in Figure 2.4).
3. Evaluation of suppliers	**3.i.** Evaluation is likely to need to cover multiple factors (from 3.1 in Figure 2.3). **3.ii.** Evaluating suppliers for digital maturity/needs will not be straight-forward, but spot-check surveys can help to highlight broader industry trends including areas of common interest and digital non-interoperability (from 3a in Figure 2.3 and EDI #2 in Figure 2.4).
4. Selection of suppliers	**4.i.** The selection criteria must be robust (from 4.1 in Figure 2.3). **4.ii.** Plan the mix including different capabilities for different purposes (from 4.2/4b in Figure 2.3). **4.iii.** If considering the launch of a Supplier Association, do so with a relatively small membership or perhaps use New Product Development as an alternative (from 4.3 and 4a in Figure 2.3).
5. Launch of programme	**5.i.** Use the power of the voice of the customer (from 5.1 in Figure 2.3). **5.ii.** Break the stereotypes to inspire and avoid apathy (from 5a in Figure 2.3).
6. Operation & support of programme	**6.i.** Establish and maintain a backbone support organisation and, as appropriate, draw in expertise from third parties (from CL #1 in section 2.3.1 and PLM #2 in Figure 2.4). **6.ii.** The operating model can be flexible, but agreeing guiding principles and using project charters may help with communication and engagement. Maintain a balance between top-down goal setting in combination with bottom-up learning by doing. Use events with all suppliers in attendance to ensure that the same message is being given to all at once (from 6.1/6.3 in Figure 2.3, COI #1 in section 2.3.2, and DMU #1 in Figure 2.4). **6.iii.** Promote the culture of a learning organisation and establish a network of change agents (from 6.2 and 6a in Figure 2.3). **6.iv.** Communities of practice may help to facilitate physical and virtual modes of collective learning (from CL #2 in section 2.3.1 and supplementary #5 in Figure 2.3). **6.v.** Set policy, and keep it under review, for sharing through either open-access or non-disclosure (from 6b in Figure 2.3)
7. Delivery of short term results	**7.i.** Use demonstrators and quick-wins to promote the concept of agility (sprints) and the minimum viable product (from 7.3 in Figure 2.3 and PLM #3 in Figure 2.4). **7.ii.** Recognise that at the start some may need more support than is the vision for the longer term and that it takes time to build trusting relationships. Therefore, be prepared to configure the approach to suit. Events on a 1:1 basis may help with engagement, diagnostics and prioritisation (from 7.1/7.2/7a in Figure 2.3 and DMU #2 in Figure 2.4).
8. Growth of results for the longer term	**8.i.** Create a common vision and vocabulary (from CL #3 in section 2.3.1). **8.ii.** Enhance long-term strategic road-mapping to include digital systems and data. Clearly articulate both the expectations and the value proposition (from 8.2/8a/8b in Figure 2.3 and INT #3 in section 2.4.2). **8.iii.** Each supplier must own their actions/roadmap. Install a feedback loop which includes monitoring of any 'knock-on' cumulative effects (from 8.4 in Figure 2.3 and EDI #3 in Figure 2.4). **8.iv.** Keep it fresh - activities may be performed in phases (from 8.1/8.3 in Figure 2.3).
9. Embedding into routine business	**9.i.** Integrate into the process for supplier performance management (from 9.1/9a in Figure 2.3). **9.ii.** Develop the concept of a minimum standard into a maturity model (from INT #2 in section 2.4.2 and DMU #3 in Figure 2.4). **9.iii.** Focus on inter-org or building the supplier's capability to self-improve (from 9.2 Figure 2.3).

Figure 2.5: Final version of the 'background' process steps & guidelines for SD/DT

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2.6   Summary of research gap and key implications from this chapter

Many have studied fragments of my research space; however, none have looked at the whole. This is perhaps unsurprising since there are aspects of complexity and wickedness (Figure 1.2). A Digital Enterprise requires a suite (plural) of integrated enterprise-wide digital technologies. Furthermore, these must be adopted and diffused into a complex supply base (i.e. firms may not be receptive and/or may lack the capability).

The research gaps which I have identified and targeted through chapter 2 are: (i) the use of SD to facilitate DT (Figure 2.2; CAPS, 2014; Watts and Hahn, 1993), and (ii) organisational learning in complex supplier networks (Lane, 2001). Orlikowski and Barley (2001) argue that, because of important epistemological differences between the research fields of information technology and organisational studies, much can be gained from greater interaction between them. They call for a fusion of perspectives and refer to such "*hybrid studies*" as being different from the mainstream of both fields.

I have made the following contributions in chapter 2:

a) Introduced the nine-step SD process through synthesis.

b) Identified that SD is a viable process to be used for DT and shown there are few alternatives.

c) Generated a 'background' framework of SD/DT process steps, guidelines and considerations with which to initiation fieldwork.

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THEORETICAL FRAMEWORK

Explaining the theories and concepts used in my research

Chapter 1 set the scene and introduced my research aim as being to: "*Define the supplier development (SD) process for its use in an Extended Enterprise to facilitate and support organisational change towards a Digital Enterprise*". Chapter 2 reviewed literature and found that SD had only been used marginally to date for digital transformation (DT) or its antecedents. But, it could potentially play a much stronger and more influential role. An initial version of the SD/DT process steps and guidelines were synthesised for use in my fieldwork.

Now, chapter 3 explains the key theories and concepts used by scholars of SD and DT in order to build a theoretical framework for my research. This chapter is divided into seven sections from 3.1 to 3.7. It begins by introducing theory in section 3.1 and constructing the framework in section 3.2. The three key aspects of the theoretical framework are then explained. These are: contextual factors to characterise firms in section 3.3, Waypoint A to study supplier choice in section 3.4, and Waypoint B to study diffusion and organisational adoption in section 3.5. Finally, section 3.6 explains that my research paradigm is that of critical realist, and section 3.7 summarises and draws out the key implications. A bullet-point executive summary is given overleaf for those who prefer this format.

Section 3.1:   Overview of theories and the key concepts associated with them

- Six theories are introduced, including: institutional, organisational learning, knowledge transfer, and diffusion of innovation.

- Associated concepts are introduced, including: learning cycles, dynamic capability, absorptive capacity, downward causation, and proximity.

- A research gap is revealed in the operationalisation and measurement of absorptive capacity (Wijk et al, 2011; Roberts et al, 2012; & Lewandowska, 2015).

- My level of analysis shall include network, dyad, and firm; but, exclude people.

Section 3.2:   Theoretical framework created for my research

- Interfirm knowledge transfer is modelled as donor–recipient.

- Waypoints A and B are placed on the journey towards a Digital Enterprise. Notionally, they are set at the transition from short term to growth in results (SD/DT steps 7 to 8) and during the embedding into routine business (steps 8 & 9).

Section 3.3:   Contextual factors to characterise firms

- Seven contextual factors are identified and a proxy is readily available for most.

- A situational approach is developed as a proxy for the role of the firm in new product development. The specificity of digital systems and tools is not included.

- A new approach is developed for the operationalisation and measurement of relative absorptive capacity using supplier scorecards.

Section 3.4:   Studying progress at Waypoint A

- Supplier choice is modelled using institutional theory.

- Responses to SD/DT are assumed to be limited to 5 options (acquiescence, etc.).

Section 3.5:   Studying progress at Waypoint B

- Diffusion and organisational adoption is modelled using a fusion of institutional and organisational learning theories.

- Adoption rates are predicted to rise after the setting and sharing of best-practice.

Section 3.6:   Research question, scope, and paradigm

- My research paradigm is that of critical realist.

Section 3.7:   Summary of key implications from this chapter

- Contributions from this chapter are listed. Also, the alternative research directions which were discounted are explained.

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3.1   Overview of theories and the key concepts associated with them

Scholars of SD have had a tendency to be somewhat insular and to be more applied than theoretically grounded (Sucky and Durst, 2013). Hence, section 2.3 of my literature review expanded the scope to include organisational learning processes with applicability to SD. This exposed the importance of the relationship between learning, knowledge, change, and diffusion which is central to my research.

Scholars of DT are far more numerous; therefore, I will narrow the scope of this review to the theoretical models which they have used for adoption at firm or supply chain level. According to Oliveira and Martins (2011), the most commonly used are: the diffusion of innovation (DOI) theory; the technology, organisation and environment (TOE) framework; and combined theories which often include institutional theory. As digital technology becomes ever more complex, the latter are recommended in order to gain a better understanding of the adoption phenomenon. A recent study in the automotive supply chain, for example, uses a combination of DOI, TOE, and institutional theory (Simoes et al, 2019).

The following contents of section 3.1 give an overview of these theories and concepts which have been most commonly used by scholars of SD and DT. This can become a complex web. Therefore, to aid the reader, I have included a brief conclusion at the end of each sub-section when there is something of particular relevance to the construction of the theoretical framework for my research.

However, first, it is apt to mention the theories which I have not included. Cropper and Palmer (2008) provide a summary of theories most commonly used by scholars to explain inter-organisational change. The field is fragmented and the theories vary strikingly in many aspects including their treatment of the dynamic and temporal qualities of change. In addition to those which I have included, they list four others which I rejected for the following reasons. Firstly, transaction cost economics which I rejected because the link between SD/DT, financial efficiency, and organisational survival is as yet unproven. Considerable effort would need to be directed towards this in the research and it is not an area of personal interest for me. Secondly, population ecology theory which I rejected because I am studying incumbent suppliers in an environment where the pace of change is slow. Finally, strategic choice and resource dependency theories which I rejected because I am studying a mature industrial sector where the creation of radically new partnerships is rare.

3.1.1 Organisational learning theory

According to Argote (1999), the study of organisational learning can be traced back to the 1930's. It is usually conceptualised as a process (section 2.3), but literature on it and other closely related fields has become characterised by diverse and overlapping terminology (Vera et al, 2011). Before introducing the theory, it should be made clear that organisational learning features in DT as well as SD research. Very highly cited articles, for example, include: technology diffusion and organisational learning in business computing (Attewell, 1992) and learning to implement enterprise systems (Robey et al, 2002).

a) **Learning cycles and dynamic capability**

Organisational learning theorists commonly use the concept of cycles to learn and to drive change. It is based upon first/second/third order learning (Bateson, 1972) which later became redefined to be single/double/deutero loop learning (Argyris and Schon, 1978). Single-loop learning refers to incremental improvements in existing ways of doing things. Vera et al (2011) describe it as occurring when "*a mismatch between intended and obtained outcomes is detected and corrected without changing the underlying routines that govern the behaviours*". Double-loop learning involves reflexivity and leads to the learning of new behaviours rather than the refining of existing skills. Vera et al (2011) describe is as occurring when "*a mismatch is detected and corrected by first changing the routines based on a new conception of the universe*". Deutero-loop learning is an even higher level of reflectivity that is said to occur when the learning process itself is examined and learned anew. Vera et al (2011) summarise it is as "*learning to learn".*

Helfat et al (2007) go onto define dynamic capability as "*the capacity of an organisation to purposefully create, extend, or modify its resource base*". By contrast, operational capability refers to routines which empower firms to deploy their resources to earn a living in the present (Collis, 1994; Winter, 2003; Zahra et al, 2006). Vera et al (2011) associate double-loop learning with dynamic capability and single-loop learning with operational capability. In an article cited in section 2.3.1b on business network learning, Dyer and Nobeoka (2000), suggest that the notion of dynamic capability needs to be extended beyond the boundaries of a single firm. Building upon their previous definition, Helfat et al (2007) define relational capability as "*dynamic capability with the capacity to purposefully create, extend, or modify the firm's resource base, augmented to include the resources of its alliance partner*".

b) **Absorptive capacity**

One type of dynamic capability is absorptive capacity (Vera et al, 2011). For our purposes, it can be traced back to the seminal work by Cohen and Levinthal (1990). Hislop et al (2018) define absorptive capacity succinctly as: "*An organisation's ability to understand, absorb, and use external knowledge*". Scholars often break it down into a number of discrete knowledge processes (e.g. acquisition, assimilation, transformation, and exploitation: in accordance with Zahra and George, 2002).

Many scholars point to absorptive capacity as being important to my research, for example: SD (e.g. MacDuffie and Helper, 1997; Dyer and Nobeoka, 2000; and Arroyo-Lopez et al, 2012), DT (e.g. Malhotra et al, 2005; and Roberts et al, 2012), inter-organisational and buyer/supplier relationships (e.g. Lane et al, 2001; Volberda et al, 2010; Saenz et al, 2014), open innovation (e.g. Lichtenthaler and Lichtenthaler, 2009; Su et al, 2013; Lakemond et al, 2016), and evolutionary economic geography (e.g. Giuliani, 2010; and Malmberg and Maskell, 2010). The five articles cited against SD and DT are explored in more detail in the paragraphs below.

Dyer and Nobeoka (2000) were introduced in section 2.3.1b in relation to SD and business network learning. They performed a case study into how Toyota facilitated inter-organisational knowledge transfers across a network of first-tier automotive suppliers in Japan and North America. They pointed to the nesting of the network into smaller learning teams based upon, amongst other factors, the suppliers which achieved a certain level of absorptive capacity with regard to the Toyota Production System.

MacDuffie and Helper (1997) also conducted case studies of automotive suppliers in North America, but with Honda. The aims of the SD programmes were the same (i.e. promoting lean production and developing the associated capabilities), but the delivery was of the dyadic as opposed to network type (section 2.1). The authors used absorptive capacity to characterise what Honda experienced with their suppliers from a long-term dependency and sustainment perspective. They characterised larger suppliers as having more absorptive capacity than smaller ones, primarily because of: related prior knowledge of the traditional skills upon which lean production was based; and a stronger identity arising from technical expertise, history of successful performance, cohesive corporate structures, and high employee tenure.

MacDuffie and Helper (1997) concluded their article with the following statement: "*However, even the best transfer mechanism, applied to a highly absorptive and responsive recipient, is not sufficient to guarantee successful knowledge transfer. The fundamental lesson of Honda's BP experience is that a supplier-customer relationship which generates high motivation for learning and high trust between provider and recipient is a crucial condition for any transfer of a complicated, largely tacit body of knowledge like lean production.*"

Arroyo-Lopez et al (2012) conducted a more recent study of SD, but reached similar conclusions to the previous two. They obtained survey results from 3 buying-firms (50% response rate), 47 of their suppliers (100% response rate), and a further 7 suppliers (17% response rate) in the automotive industry in Mexico. They confirmed their hypothesis that: "*The relationship between knowledge transfer activities for supplier development and improvement of supplier's capabilities is moderated by the absorptive capacity of the supplier.*" They recommended more screening and nesting/phasing of suppliers on SD programmes on the basis of their absorptive capacity.

Malhotra et al (2005) performed an exploratory field study of the RosettaNet consortium. Their focus was the building of enterprise-level absorptive capacity in supply chains through information technology infrastructure. They concluded that: "*… enterprises have to build requisite absorptive capacity to prepare for collaborative knowledge creation with their supply chain partners. Absorptive capacity in this context is the ability of enterprises to acquire and assimilate information from their supply chain partners and to transform and exploit this information to achieve superior operational and strategic outcomes.*"

Roberts et al (2012) identify a research gap for the operationalisation and measurement of absorptive capacity. They searched for evidence of absorptive capacity in literature on information systems and identified 98 articles. They revealed shortcomings when measuring absorptive capacity solely as an asset (i.e. the firm's prior knowledge base using proxies such as the number of patents raised) and pointed to the need to measure it more consistently as a capability (i.e. in accordance with my earlier definition for both absorptive capacity and dynamic capability). They drew from other scholars when they argued that: "*To conduct valid empirical research, the conceptual domain of absorptive capacity should be effectively converted into the operational domain*".

Roberts et al (2012) also emphasised that: "… *as a knowledge-based construct, absorptive capacity is domain-specific. For example, a firm may have high absorption capacity in new product development yet have low absorption capacity in supply chain operations. Developing measures that capture the knowledge specificity of absorption capacity will strengthen construct validity and provide greater implications for managers. Hence, researchers should identify the particular knowledge domain for absorptive capacity relevant to a specific research context*."

The research gap for the operationalisation and measurement of absorptive capacity has also be characterised by its level of analysis. Wijk et al (2011) divide extant literature into that which considers absorptive capacity at the firm-level versus the dyad-level. The latter is of most interest to my research, but only four articles were identified here with four means of operationalisation: patents, publications, related technologies, and questionnaire scales. The far more recent article which they cite is by Tallman and Phene (2007) who operationalise based upon patent citations and, therefore, lack the depth sought by Roberts et al (2012). Regarding the other approaches to operationalisation, at either dyad-level or firm-level, Wijk et al (2011) explain that scholars have often had to resort to using questionnaire scales to differentiate between capabilities. Compared to other aspects of research into absorptive capacity, they conclude that progress made on operationalisation and measurement is low.

Furthermore, the research gap for the operationalisation and measurement of absorptive capacity has also be characterised by its mode of measurement. Lewandowska (2015) divides extant literature into three modes that are used in studies relating to open innovation: perceptive instruments (i.e. questionnaire scales), input-orientated indicators (e.g. research and development spend, human capital, and professionalism), and output-orientated indicators (e.g. patents). She lists strengths and weaknesses for each mode of measurement, but highlights a common problem with the lack of access to suitable data.

Conclusion drawn for the construction of my theoretical framework: Absorptive capacity is a vital concept to include. In response to the research gap which has been identified, I will seek to operationalise and measure it through supplier scorecards. These are briefly introduced next.

c) **Organisational alignment, scorecards, and maturity models**

Kaplan and Norton (1996) were the first to introduce the concept of the balanced scorecard to measure the performance of firms and align improvement initiatives. This gained much interest, but initially had a predominately intra-organisational focus (Frimanson and Lind, 2001). Subsequently, a later publication had a whole chapter on aligning external parties which took a more strategic view of supplier scorecards (Kaplan and Norton, 2006).

Cited at the time (November 2003) by Kaplan and Norton, Rolls-Royce were described like many as having a key performance indicator (KPI) supplier scorecard which only covered quality, delivery, and cost metrics. Kaplan and Norton argued that such a narrow operational approach would "*miss opportunities to align suppliers' processes and their human and information capital to enhance supply-chain performance.*" They recommended the addition of other perspectives and attributes including, as an illustrative example, the establishment of a shared objective for the buyer and supplier to extend their use of e-Commerce together.

Supplier scorecards may incorporate organisational maturity assessments. Anderssen and Jessen (2003) define organisational maturity as the "*state where the organisation is in a perfect condition to achieve its objectives*". In SD, there is a long tradition of using organisational maturity models as benchmarking and diagnostic tools (e.g. Hines, 1994; Hartley and Choi, 1996; Krause and Handfield, 1999; SC21, 2006). Similar are emerging for DT (e.g. Mahdikhah et al 2014 for PLM; NIST 2016 for MBD/E; Schumacher et al 2016 & SEDB 2017 for Industry 4.0; Klotzer and Pflaum 2017 for digitisation of manufacturing supply chains; BSI 2019 for digital manufacturing). Nevertheless, in terms of maturity models for processes in the field of supply chain collaboration, they are judged to still be in their infancy with more yet to come (Ho et al, 2019).

A few scholars have investigated the operationalisation and measurement of absorptive capacity using balanced scorecards, however, in most cases this has been for intra-organisational purposes only. An exception is McAdam et al (2010). They studied the development of absorptive capacity based innovation in a knowledge transfer partnership between a small to medium sized enterprise (SME) in Northern Ireland and a local university. They did so by following a 2-year action research programme. Their balanced scorecard was not pre-existing, and went through numerous iterations, but the researchers concluded that the approach was generally helpful.

3.1.2 Knowledge transfer theory

For my research subjects, Hislop et al (2018) categorise their knowledge management situation as heterogeneous. Multiple firms are involved who have very distinct differences (e.g. knowledge base, sense of identity, native language, etc.). Under such circumstances, Easterby-Smith et al (2008) provide a donor-recipient model of the factors which shape inter-organisational knowledge transfer. This is shown in Figure 3.1 and it helps to place absorptive capacity (section 3.1.1b).
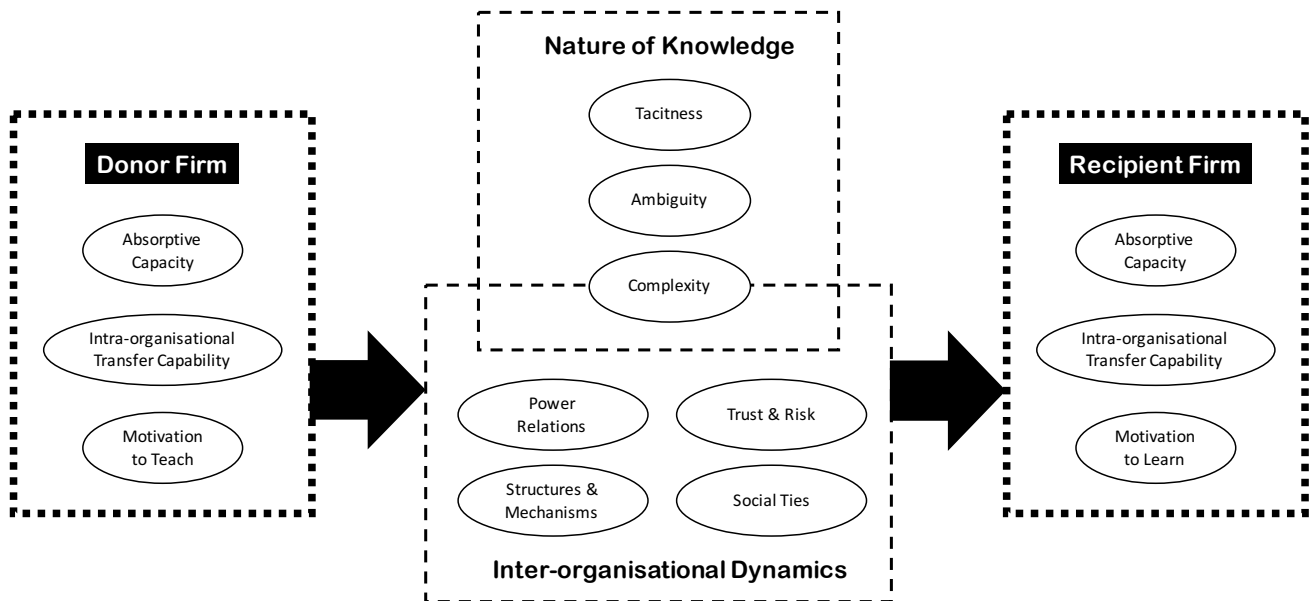
Figure 3.1: Model of factors shaping inter-organisational knowledge transfer

(Easterby-Smith et al, 2008)

Easterby-Smith et al (2008) consider both dyad and network relationships, but are noncommittal about them and call for more research into which offers the most effective platform for knowledge transfer. Categorised similarly to Figure 3.1, Winkelen and McKenzie (2011) provide a checklist of 17 practices for knowledge transfer and inter-organisational learning in collaborative networks. In comparison to Figure 2.5, there is only one notable difference in that they insist upon long-term continuity in role from individuals appointed to represent their firms. This is covered in section 3.1.6.

Conclusion drawn for the construction of my theoretical framework: Figure 3.1 will be used to underpin my theoretical framework. Absorptive capacity, intra-organisational transfer capability, and the nature of knowledge will be incorporated through my use of supplier scorecards. However, social ties will be excluded from the scope of my research and this is explained in section 3.1.6.

3.1.3 Institutional theory

Mintzberg et al (2009) categorise institutional theory as coming from the school of research where strategy formulation is taken to be a reactive process. They explain that institutional theory is concerned with the pressures that firms face from their environment. Strategy becomes a case of finding ways of acquiring economic resources (e.g. money and machinery) and converting them into symbolic ones (e.g. prestige and reputation), and visa-versa, in order to protect themselves from uncertainty. A complex and powerful set of norms emerge. To be successful, a firm must meet and master these norms which drives them, over time, to adopt similar structures and/or practices.

For my research, the outcome is not intended to be an enterprise which is fully homogeneous; yet, the process of change can be considered to be similar to that of homogenisation. Meyer and Rowan (1977) and DiMaggio and Powell (1983) use the term *"institutional isomorphism"* to describe this phenomenon in structure, process, and/or behaviour. Three modes are identified: coercive (e.g. publishing vision statements and setting requirements), mimetic (e.g. benchmarking and learning together to share and deal with uncertainty), and normative (e.g. training and exchanging experts and professional staff). Scott (2014) describes different forms of institutional activity from those which may be used to maintain and reinforce existing norms through to those which may be used to create, innovate, or disrupt. He mentions business associations and communities of practice as examples of extending institutional activities beyond single firms.

Institutional theory has been used by SD scholars in as diverse settings as the buyer-side implementation of a new SD programme by an automotive manufacturer in North America (Rogers et al, 2007) to the supplier-side adoption of new SD practices in agricultural diary supply chains in India (Yawar and Kauppi, 2018). More generically, it has also been shown to help to explain the adoption of new manufacturing practices across global industry (Ketokivi and Schroeder, 2004; Turkulainen, 2017). Furthermore, institutional theory has been used extensively in DT research. Robey and Boudreau (1999) use it to understand the processes which promote and impede information technology related change in organisations. Teo et al (2003) use it to predict the intention to adopt inter-organisational financial linkages. Currie (2011) develops an institutional theory for information technology. Pishdad and Hiader (2013) and Bohorquez Lopez (2018) develop institutional models for enterprise resource planning (ERP) systems.

a) **Downward causation and causal loops**

Writing about causal power, Elder-Vass (2010) explains that business structures and associations exert a "*downward causation*" influence over their constituent members. My research circumstance fits with that classified as weak intensity (Emmeche et al, 2000), because the suppliers are free agents and are not constrained by regulatory or legal requirements to act of their own accord. Also, an interweaving of downward and upward looped processes is an important feature. Jong and Nooteboom (2000) describe them as iterative processes of mutual adjustments between the buyer and supplier in order to sustain strong and effective working relationships. In their study, they also reveal that physical location can influence the causal loops.

Conclusion drawn for the construction of my theoretical framework: Weak intensity of downward causation and a process of mutual adjustment point to suppliers having choice. They may not respond positively to the SD/DT process. The use of institutional theory to study this phenomenon within my theoretical framework is explained in more detail in section 3.4.

b) **Institutional thickness**

The concept of institutional thickness is often attributed to the seminal work by Amin and Thrift (1994) on regional development. They specify four factors within a given locality. Firstly, the strong presence of a plethora of different kinds of organisation. Secondly, high levels of interaction amongst these organisations. Thirdly, the development, as a result of these interactions, of patterns of coalition and collective action. Finally, a sense of identity amongst participants that they are involved in a common enterprise. In the most favourable cases, they forecast outcomes which include: formal and tacit knowledge capture, sharing, and reuse; flexibility to learn and change; and high innovative capacity.

Thick is not necessarily better than thin e.g. the risk of lock-in (Asheim, 2000) and the need to contextualise (Rodriguez-Pose, 2013). The extant literature was revisited by Zukauskaite et al (2017) who stated that "*indicators of institutional thickness are rather hard to estimate*" and "it *is important to deal with the question of thickness for what … thickness has to be related to a concrete phenomenon on which it might have either a positive or a negative impact*".

Conclusion drawn for the construction of my theoretical framework: Institutional thickness helps to build up to the concept of proximity which is covered in section 3.1.3d.

c) **Institutional distance**

The concept of institutional distance is often attributed to the seminal work by Kostova (1999) on multinational enterprises and the transfer of practices from a parent firm to its foreign subsidiary(s). She defines it as the difference between the organisational profiles (regulatory, cognitive, and normative) at the different sites. For practices to be successfully transferred there must be: an organisational culture at the recipient which is supportive of learning, change, and innovation; compatibility between the values implied by the practice and the underlying values in the recipient's organisational culture; and commitment and trust in the transfer coalition.

Numerous scholars have used the concept of institutional distance in their research; however, relatively few have directed its use towards supply chains. Exceptions include: Bhakoo and Choi (2013) who explored heterogeneity in a healthcare supply chain; Busse et al (2016) who assessed ethics and risk in global supply chains; Dong et al (2017) who studied e-collaboration; and Ho et al (2017) who studied knowledge transfer and trust. There has been little attention to power regimes; although, Pallot et al (2010) applied the concept to distributed working environments.

Conclusion drawn for the construction of my theoretical framework: Institutional distance helps to build up to the concept of proximity which is covered in section 3.1.3d.

d) **Proximity**

As the name suggests, the concept of proximity has many similarities to that of institutional distance; but, it has become more favoured in economic geography literature (e.g. Regional Studies, 2015). Knoben and Oerlemans (2006) review extant literature and list seven dimensions: institutional, cultural, social, technological, cognitive, organisational, and geographical. They identify three (geographical, organisational, and technological proximity) as being of most importance to inter-organisational collaboration.

Schmitt and Biesebroeck (2013) use the concept of proximity to reveal heterogeneous effects in automotive supply chains. Hansen and Mattes (2018) explore the role played by proximity in power regimes. Research into DT and proximity is still very sparse (Pallot et al, 2010); however, Dallasega et al (2018) find evidence of digital technologies in construction supply chains mainly influencing geographical, organisational, technological, and cognitive proximity.

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Increasingly, theorists are shifting from a static to a dynamic perspective of proximity. Balland et al (2015) lay the foundations for this. The dominant processes which they identify are: learning, institutionalisation, agglomeration, integration, and decoupling. The first two of these are covered in sections 3.1.1 and 3.1.3, the third is defined in a manner which shows itself to be very similar to that described in section 3.1.3b, the fourth was included in section 2.3.1a through the work of Alfalla-Luque et al (2013), and the fifth will be tackled later in section 3.1.6. It is comforting to be able to draw this comparison from an independent source having arrived at these processes through other routes myself.

Finally, to build upon section 3.1.1a, a brief introduction to the concept of relative absorptive capacity. Scholars using cognitive proximity (section 3.1.3d) or cognitive distance (section 3.1.3c) often trace their definitions and measurements back to relative absorptive capacity (Lane and Lubatkin, 1998). The concept allows for the fact that a firm may not have an equal capacity to learn from all others. There is a learning construct, for example, as shown in Figure 3.1. Furthermore, there may be an optimum (e.g. Nooteboom, 1999 and 2006). That which is large enough for firms to offer each other something new, but not so large that they cannot understand each other or reach agreement.

Conclusion drawn for the construction of my theoretical framework: Proximity provides a broad holistic view, therefore, I will use it to prioritise the contextual factors for my theoretical framework. See section 3.3.

3.1.4 Diffusion of innovation (DOI) theory

DOI theory is usually attributed to Rogers (1995, 2003), although his work includes and is built upon the work of many others. He identifies five types of variables that determine an innovation's rate of adoption: perceived attributes of the innovation (i.e. relative advantage, compatibility, complexity, trialability, and observability); type of innovation-decision (i.e. optional, collective, or authority); communication channels (e.g. mass media or interpersonal); nature of the social system (e.g. in norms, degree of network interconnectedness, etc.); and extent of change agents' promotion efforts. Adopters are categorised as innovators, early adopters, early majority, late majority, or laggards.

For studies into the adoption of digital technology at firm-level, a common use of DOI theory is through an assessment of the digital technology's innovation attributes i.e. its relative advantage, compatibility, complexity, trialability, and observability (e.g. Kapoor et al, 2014; Oturakci and Yuregir, 2018). This may then be used in combination with other theories such as institutional theory or the TOE framework (e.g. Oliveira and Martins, 2011; Simoes et al, 2019).

Conclusion drawn for the construction of my theoretical framework: Aspects of DOI theory are similar to others in section 3.1 and their mapping is shown in Figure 3.3. I will use the 'perceived attributes of the innovation' later in Chapter 7 to review an aspect of the supplier scorecards.

3.1.5 Technology, organisation, and environment (TOE) framework

The TOE framework was devised by Tornatzky and Fleisher (1990). In their book they give an example of the boundaries between firms using the case of buyers in the automotive sector who were unsuccessful when they simply tried to give their suppliers deadlines for the installation of computer-aided-design (CAD). Tornatzky and Fleisher (1990) propose that there are three contextual factors that influence the process by which firms adopt and implement technological innovations: technology (e.g. its characteristics and availability), organisation (e.g. its size, structures, and slack), and environment (e.g. the market structure and regulation). The TOE framework is occasionally used alone to model information technology at firm-level, but it is more common for it to be combined with other theories (Oliveira and Martins, 2011).

Conclusion drawn for the construction of my theoretical framework: Aspects of TOE are very similar to others in section 3.1 and their mapping is shown in Figure 3.3. Technology is covered in both the entry for technological proximity and absorptive capacity.

3.1.6 People and relationship theory

The level(s) of analysis in my theoretical framework could potentially span that of the network, dyad, firm, and individual. Historically, the latter has been the least researched; however, interest is now growing (e.g. Wang et al, 2018). Also, Figure 3.1 pointed to social ties as being one of the many factors to consider for inter-organisational knowledge transfer. Nevertheless, I have chosen to exclude it. My reason for doing this is driven by research priorities and the impracticality of gathering suitable data during three years of fieldwork. Below is my justification from the perspective of theory.

I turn first to Thompson (1967) as one of the formative and influential researchers of organisations to start to argue my case for not including the individual in my theoretical framework. In his work, he frequently refers to circumstances when people in organisations are omnipotent. However, he also states that this is not the case under any of the following three conditions: (i) when the complexity of the technology exceeds the comprehension of the individual, (ii) when the resources required exceed the capacity of the individual to acquire, and (iii) when the organisation faces contingencies on more fronts than the individual is able to keep under surveillance. All of these conditions apply to my research (see, for example, Figure 1.2).

This, of course, does not mean that the people in the firms which I am studying are powerless puppets. It is simply a measure of degree and influence. The following quotes help to explain this:

> "*The higher level entity … acts through the individual: those properties that the individual acquires by occupying the role are essentially properties of the organisation localised in the individual.*" **Elder-Vass (2010)**

> "*Here, it is the specific combination of effort, rather than the powers of atomised individuals, that is the [dominant] causal property of the group or institution.*" **Vincent & Wapshott (2014)**

> "*The organisation is an appropriate level of analysis because it is in organisations that learning occurs … Ultimately, diffusion is a field-level process in which higher-level institutional effects unfold through lower-level organisational decisions … Further shaping the decision context for organisations at the field-level is the presence of proselytizers who actively persuade members of a social domain to adopt a diffusing innovation.*" **Chandler and Hwang (2015)**

The dominant proselytizers in the last quote manifest themselves in my research as the people whom I refer to as change agents (see 6.iii. in Figure 2.5). Their organisational power base will come from them being expert, referent, rewarding, coercive, and/or legitimate (Hinkin and Schriesheim, 1989). Furthermore, they must also network and communicate in order to influence effectively. Some of the change agents in my research will inevitably be more skilled at doing this than others, but regardless they are acting as agents of the firm that appoints them. I will treat it as a property of the firm as to whether they appoint a suitable candidate to be their change agent, track their progress and, as required, intervene with support and encouragement.

3.2. Theoretical framework created for my research

Figure 3.2 shows the theoretical framework which I created for my research. I take the donor-recipient model for knowledge transfer from Figure 3.1 and use contextual factors to position each firm in my study group within it. The contextual factors are based upon previous research into supply chains (section 3.1.3d) and I identify a suitable proxy to measure each (section 3.3). I then set two waypoints in order to study each firm's response, progress, and outcome from the SD/DT process:

- Waypoint A assesses the initial period of launch, uptake, and engagement through the delivery of short term results (i.e. up to step 7 in the SD/DT process). Suppliers have choice and may not respond positively (section 3.1.3a). Therefore, I study their approach and behaviour using institutional theory (section 3.4) e.g. is there evidence of acquiescence? This first waypoint is also a decision-point for continued membership of the SD/DT programme and it is possible that some of the firms in my study group may not progress beyond it.

- Waypoint B studies the longer term results and the embedding into routine business (i.e. steps 8 and 9 in the SD/DT process). Here, the individual and collective learning outcomes of firms can be more meaningfully assessed, because their level of engagement has been previously confirmed at Waypoint A. Therefore, I look to a fusion of institutional and organisational learning theory to study them (section 3.5) e.g. is there evidence of adoption and diffusion?
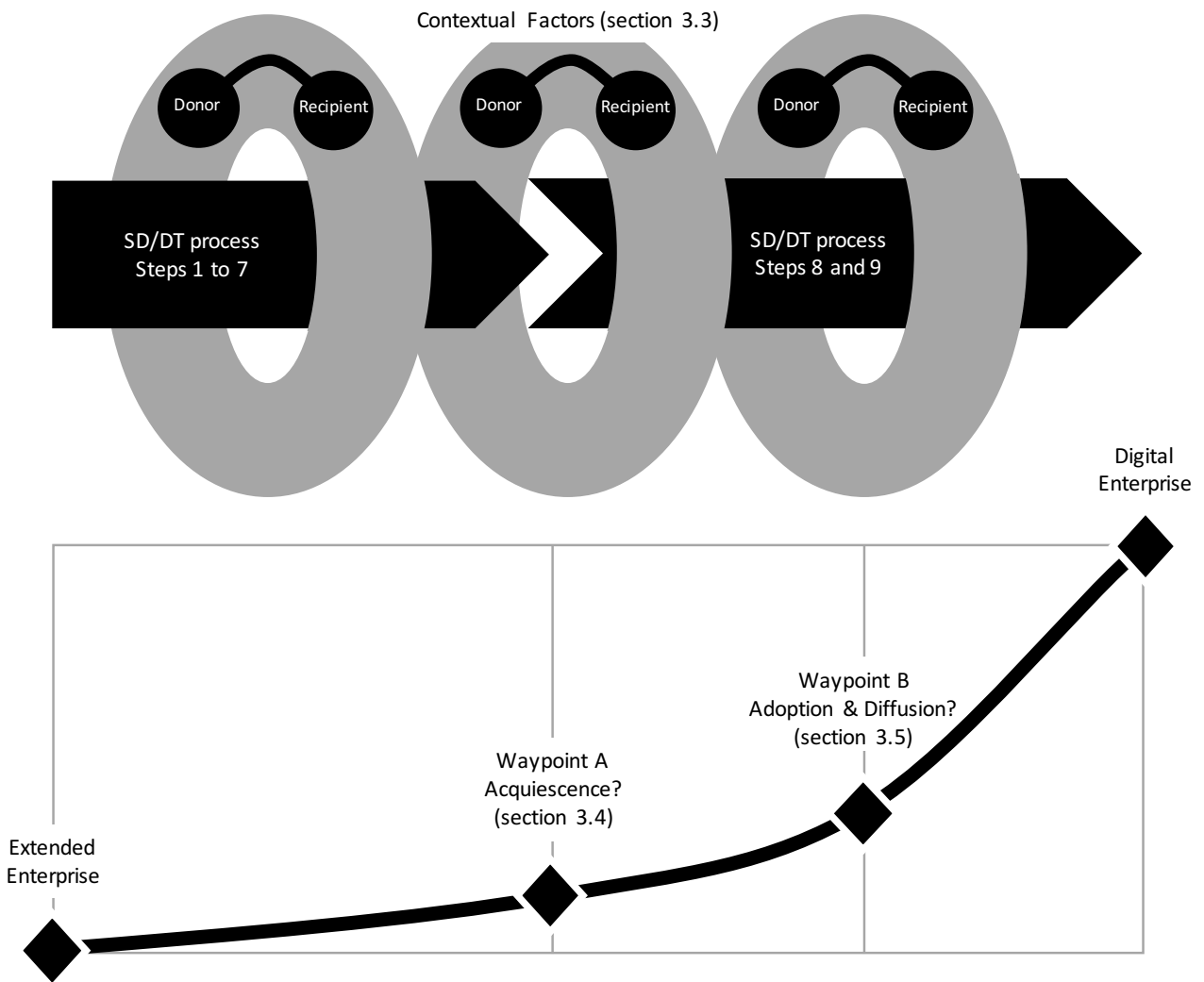
Figure 3.2: Theoretical framework created for my research

3.3 Contextual factors to characterise firms

Salimian et al (2017) provide a fitting introduction to this section: "*Effective implementation of SD activities is contingent upon a thorough understanding of situational/contextual factors that moderate the performance impact of SD schemes … [it] is not a universal concept which could always bring many benefits to organisations*". Figure 3.3 lists the contextual factors which I shall use.

Concept	Proxy	Level of analysis	Measurement and source
Geographical Proximity (from sections 3.1.2, 3.1.3b, 3.1.3c, and 3.1.3d)	Location of firm	Network	Established approach taken (e.g. Knoben and Oerlemans, 2006) To protect the identity of firms, they shall be grouped into region (Asia, Europe, and North America). Although, further granularity on regional clustering is retained for analysis if required. The most dominant (HQ) location shall be used for multi-national firms.
Organisational Proximity (from sections 3.1.2, 3.1.3c, 3.1.3d, 3.1.4, and 3.1.5)	Size of firm	Firm	Established approach taken (e.g. Salimian et al, 2017; Qamar & Hall, 2018) The number of employees in the firm shall be used and, to suit the range in my study, grouped as: small firms (<500), medium firms (500 to 5000), and large firms (>5000).
	Strategic alignment	Dyad	Established approach taken (i.e. Cox, 2014) The position of the firm in the procurement portfolio analysis as ascribed by the buyer at Rolls-Royce. The categories application to my study group of firms are: aligned, sub-optimal misalignment, or dysfunctional conflict.
	Tier in the Extended Enterprise	Network	Established approach taken See section 1.2.2 and Figure 1.3
Technological Proximity (from sections 3.1.2, 3.1.3d, 3.1.4, and 3.1.5)	Role of firm in New Product Development	Dyad	**Situational approach required** See section 3.3.1
Power Relations (from sections 3.1.2, 3.1.3c, 3.1.3d, 3.1.4, and 3.1.5)	Power Regime	Dyad	Established approach taken (i.e. Cox, 2014) The position of the firm in the procurement portfolio analysis as ascribed by the buyer at Rolls-Royce. The categories application to my study group of firms are: buyer dominance, supplier dominance, or interdependence.
Relative Absorptive Capacity (from sections 3.1.1b, 3.1.2, 3.1.3b, 3.1.3c, and 3.1.3d)	Supplier Scorecard (from sections 3.1.1c, 3.1.4, and 3.1.5)	Dyad	**New approach required** See section 3.3.2

Figure 3.3: Contextual factors to characterise firms

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3.3.1 Measurement of technological proximity using the role of the firm in NPD

Some of the articles reviewed in section 3.1.3 refer to the need for contextual factors, when appropriate, to be situational and considered in relation to the specific phenomenon being studied (e.g. Zukauskaite et al, 2017). Therefore, for my study of SD/DT, I judged that such an approach was appropriate for technological proximity. Figure 3.4 shows the measurement criteria which I developed from concepts on supplier integration during new product development (NPD) defined in Monczka et al (2000). In my case, categorisation is not in any hierarchical order nor on a maturity scale. But, labels from NPD1 to NPD9 are provided for ease of reference. My categories for technological proximity measure the fundamental basis of the supplier firm's dyadic relationship with the focal (buyer firm) in the Extended Enterprise. For each technological proximity category, a different value proposition is likely for the adoption of digital technologies and the move towards a Digital Enterprise.

			DESIGN lens	**MAKE lens**	**BUY lens**
Design/Make Design responsibility held by the supplier	**High** Level of physical integration to the buyer	NPD 1	Simultaneous engineering is likely to be required	Driven entirely by the supplier	Early supplier engagement is essential
	Low Level of physical integration to the buyer	NPD 2	Manual controlled release is possible	Driven entirely by the supplier	Supplier selected before design freeze
Make-to-Print Design responsibility held by the buyer	**Major** Collaboration required with the buyer	NPD 3	Simultaneous engineering is likely to be required	Buyer may consider 'digital make' before release	Early supplier engagement is essential
	Intermediate Collaboration required with the buyer	NPD 4	Design for manufacture (DfM) is required	Design for manufacture (DfM) is required	Supplier selected before design freeze
	Modest Collaboration required with the buyer	NPD 5	No, or minimal, DfM is required	Industry standard tolerances are typically used	Supplier can be selected after design freeze
Sub-Tier Raw materials and/or proprietary processes which may be developed & controlled by supplier	**Specialised**	NPD 6	Design for manufacture (DfM) is required	Driven by the supplier	Supplier selected early and certainly before design freeze
	Generic	NPD 7	No, or minimal, DfM is required	Industry standard processes	Supplier can be selected after design freeze
Service Provider From an Airworthiness perspective, do not hold the design or production authorities for the physical hardware	**Product** (e.g. logistics services)	NPD 8	No design is performed	No make is performed (only buy)	Access may be required to back office systems
	Process or Tools (e.g. skilled resources) (or software systems)	NPD 9	Access may be required to back office systems	Access may be required to back office systems	Pricing may be on the basis of T&M or unitised

### Figure 3.4: Measurement of technological proximity using the role of the firm in NPD

(adapted and developed from Monczka et al, 2000)

I considered, but discounted, two alternative approaches to that shown in Figure 3.4 for the measurement of technological proximity. Firstly, I considered measuring the strength of alignment between the supply chain strategy and the functional or innovative characteristics of the product (Fisher, 1997; Harris et al, 2010). But, I found this approach to offer little value; because, I was dealing with incumbent suppliers and there was already good alignment for all of those in my research study group. Secondly, I considered measuring each type of digital technology within the Extended (Digital) Enterprise and the match between it and the supplier. Pawar and Driva (2000), for example, list three main components for electronic trading to take place: standards to structure data, communication infrastructure to enable the flow, and software to transmit and translate. I wrestled most with how to deal with the specificity required here. After careful consideration, I decided that my research would assume that technological proximity, and therefore inter-firm relationships, are agnostic to the different brands of digital software and infrastructure used by firms.

There is a case for taking the opposite position. For example, the focal firm in an Extended (Digital) Enterprise may be seeking to mandate specific brands in order to be assured of digital interoperability and cyber-security. Adoption may be easier for suppliers where the same, or highly compatible, brands are already being used. Furthermore, there is another subtlety which may contribute to some suppliers taking a more cautionary approach than others. At present, many of the international standards required for exchanging and collaborating with digital data are immature or incomplete. Consider this potential scenario: (a) supplier working with different focal firms finds that they mandate different digital brands; (b) supplier is forced to choose sides because the cost and complexity of dealing with incompatible digital brands is prohibitive; (c) supplier becomes locked-in to one focal firm; (d) supplier loses power; (e) focal firm leverages power to extract data and knowledge; (f) focal firm stands up another, cheaper, supplier and passes data and knowledge to them via the SD/DT process; and (g) original supplier ceases to trade unless they foresee events and pursue other business opportunities e.g. not being so eager to adopt and acquiesce at point (b).

However, Figure 3.5 provides a glimpse of the complexity which is involved in gathering data, and keeping it up-to-date, regarding the specificity of digital systems and tools. The results support the findings from others on the low state of industrial readiness for digital manufacturing (e.g. Harris, 2018 & 2019). Knowledge and expertise is needed to determine which of these brands will operate seamlessly together. Furthermore, it is a snapshot in time and the pace of change is increasing.
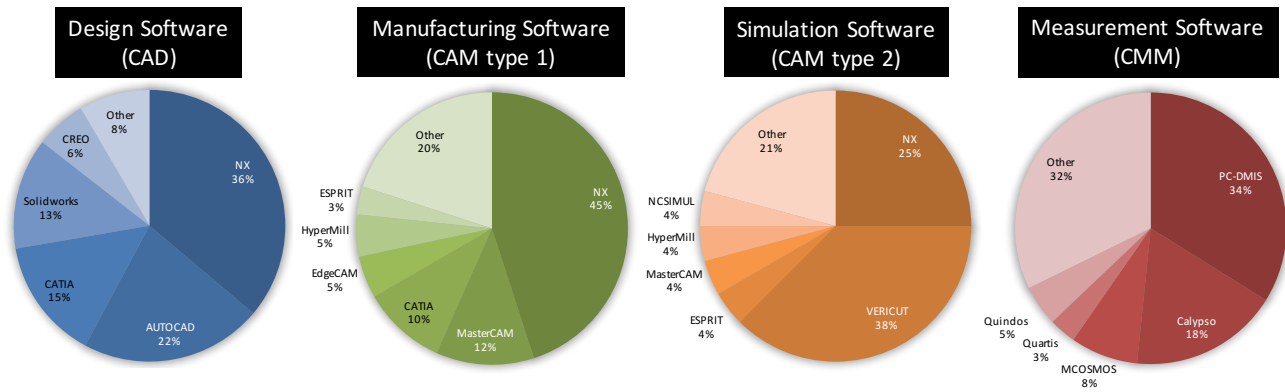
Figure 3.5: Survey showing the complex specificity of digital systems and tools

(responses received from 63 suppliers to Roll-Royce; 55% response rate to a survey in 2019Q4)

Hence, in addition to the impracticalities of gathering and using such data, I decided that my research would ignore the specificity of digital systems and tools for the following reasons:

a) ***Functionality drives the value proposition:*** Figure 3.4 gives insight into the desired functionality of the digital systems and tools from which an estimate can be made of the value proposition. Like any asset, firms will budget and invest to upgrade, or replace, their digital systems and tools.

b) ***My theoretical framework supports convergence over time:*** Adoption and diffusion occurred with Total Quality Management (Furusten, 2013; Scott, 2014). It is reasonable to assume that similar will occur here and that it can be modelled using institutional theory. The value proposition grows as functionality grows. Under rising pressure, unresolved issues are resolved.

c) ***Casting the right shadow:*** The vision for a Digital Enterprise infers that it's digital system and tools are interoperable (Figure 1.4). Thus, it could send mixed messages, and distract from the intended direction of travel, if they were used as a prime attribute to contextualise firms.

d) ***Alternative forums for resolution:*** Two forums were identified by Rolls-Royce representatives on international standard committees, namely: A&DPLMAG (2014) and AESQ (2015). It has been shown to be mutually advantageous in SD programmes if multiple buying firms can take a collegiate approach with their common supplier firms (Aune et al, 2013).

NOTE: Although I did not explicitly ask at interview, my perception is that firms would see the specificity of digital systems and tools to be more an SD/DT process issue than a contextual factor. I cover it later in section 5.2.1 when I explain how the collective power of the supply base was sought to be leveraged through the SD/DT process. There is a long way yet to go to resolve this matter.

3.3.2 Measurement of relative absorptive capacity using supplier scorecards

A research gap in the operationalisation and measurement of absorptive capacity was introduced in section 3.1.2b (Wijk et al, 2011; Roberts et al, 2012; and Lewandowska, 2015). Therefore, I had to develop a new method to study it which is summarised in Figure 3.6.

Supplier Scorecard (Technology)	Satisfactory	**AC2** Capable and aligned supplier with operational challenges	**AC1** Capable and aligned supplier without operational challenges
	Unsatisfactory	**AC4** Incapable/unaligned supplier with operational challenges	**AC3** Incapable/unaligned supplier without operational challenges
		Unsatisfactory	Satisfactory
		Supplier Scorecard (Operational)	

Figure 3.6: Measurement of relative absorptive capacity using supplier scorecards

Supplier scorecards are introduced in section 3.1.2c. They have evolved at Rolls-Royce since the firm were referenced by Kaplan and Norton (2006) and, for the last decade, have included technology as an attribute. Because the scorecard combines multiple attributes, Rolls-Royce call them an Integrated Supplier Scorecard (ISS) and use them with a Supplier Engagement Plan (SEP). Suppliers have an ISS/SEP if the buyer at Rolls-Royce assesses them as being strategically important and/or operationally significant. The list of ISS/SEP suppliers is subject to continual review. The number peaked at 122, and changed by no more than 5% per year, over the duration of my research.

Supplier scorecards are used to structure the monthly business reviews held between Rolls-Royce and its suppliers. They are seen as a joint output. As a minimum, they must be completed quarterly and uploaded into a central repository. For the first 3 years of my research (2016 to 2018), the format remained unchanged. However, as explained in chapter 5, this was changed for the start of 2019 onwards. In all cases, supplier scorecards are completed independently of the prime researcher.

Figure 3.7 explains how my new method of measuring relative absorptive capacity using supplier scorecards meets the dimensions and components specified by Zahra and George (2002). The supplier scorecards are constructed using a series of questions against which an assessment is made that scores the supplier from three (fully achieved) to zero (not achieved). Scores are summated to give an overall score with the threshold between satisfactory/unsatisfactory performance set at 70%.

Dimensions of absorptive capacity (Zahra and George, 2002)	Components and corresponding role (Zahra and George, 2002)	Supplier scorecards (Assessment of those used by Rolls-Royce by the prime researcher)
Acquisition	• Prior investments • Prior knowledge • Direction • New connections	The supplier scorecard (technology) benchmarks the supplier and ranks their technology (product, process, and system) on the basis of 'best in class'. The capability, availability, and track record of their own internal staff are considered plus the strength of their external networks (universities, research centres, and professional bodies). Also, the level of investment in the acquisition and development of technology directed towards Rolls-Royce must satisfy a threshold which is defined as a percentage of the suppliers' annual turnover with Rolls-Royce.
Assimilation	• Understanding • Interpretation • Comprehension • Learning	At least annually, a technology road-mapping and matching event must be performed between Rolls-Royce and the supplier. To gain a score of three (full marks) on the supplier scorecard, there must be full alignment between the strategies of Rolls-Royce and the supplier.
Transformation	• Internalisation • Conversion • Recodification • Bisociation	The expectation which is set by Rolls-Royce in their supplier scorecard (technology) is that the best available technology is currently being deployed onto their products and programmes. Should this not be the case, then a score of less than three (i.e. not full marks) is awarded and the transformation effort is then tracked through the supplier engagement plan.
Exploitation	• Use • Implementation • Core competencies • Harvesting resources	The supplier scorecard (technology) uses the TRL/MCRL approach plus project management tools to govern programmes and track their maturity through to full implementation and deployment. For my method of measuring absorptive capacity, I have also used the supplier scorecard (operational) in Figure 3.6. It can be a leading indicator for distractions and/or opportunities on technology programmes. If operational performance is unsatisfactory, then the challenges could become a distraction which divert the suppliers' resources. Alternatively, it may help to give them a focus or impetus for speeding up their implementation and deployment.

Figure 3.7: Supplier scorecards meet the dimensions of absorptive capacity

3.4   Studying progress at Waypoint A

Waypoint A is shown in Figure 3.2 and is set notionally at the transition from the delivery of short term results (i.e. step 7 in the SD/DT process) to the growth of results for the longer term (i.e. step 8 in the SD/DT process). I look to institutional theory to help to understand this initial period of launch, uptake, and engagement.

Although not directly referencing it, Aitken (1998) from section 2.2 reveals glimpses of institutional theory in his study of supplier associations and lean initiatives. He codifies supplier response strategies as either: constructive, passive, withdrawal, or destructive. He argues that the role of the supplier should not be considered as a passive recipient of the focal firm's actions to spread good practice. However, this important aspect has not been well studied since. In section 2.3.1b, I cite Lane (2001) as highlighting how it contributes to the research gap in supply chain learning. Furthermore, Rogers et al (2007) criticise the whole body of SD research as generally not considering the symbolic role in maintaining institutional legitimacy. I wish for my research to help to close these gaps.

However, Mintzberg et al (2009) raise some concerns over the use of institutional theory and warn of the dangers of expecting a firm to respond too rationally to a complex environment it cannot control. Nevertheless, they point to its successful use at the "*mature stage*" of a firm's lifecycle. Here, they describe circumstances very similar to my own. Stable and well established firms being subject to renewal as their environment is changed through the diffusion of new technology. Furthermore, Gadde et al (2010) recommend the use of institutional theory to inform supply network strategies in situations where problems are difficult to assess and solve through formal approaches (i.e. when it is more than just a matter of writing new contracts or relying upon legislation).

In one of the seminal works on institutional theory, Oliver (1991) suggests that the options open to firms to respond to institutional processes are limited to: acquiescence, compromise, avoidance, defiance, or manipulation. A recent example is provided in a case study by Acosta et al (2014). They consider three tiers of a supply chain in the Colombian (Latin America) food industry together with their local industry association. They investigate how the focal firm integrates the requirements of a SD programme and diffuses it to its sub-tier suppliers. Their research is focused upon how this impacts social welfare and environmental (green) sustainability.

Acosta et al (2014) find evidence of the three lowest confrontation strategies (i.e. acquiescence, compromise, and avoidance), but no evidence of those which are more confrontational (i.e. defiance or manipulation). They hypothesise that this is because of the dominant power of the focal firm and the corresponding strength of the coercive institutional pressure. They also highlight the mediating role of network ties through the local industry association. They argue that this helps to adapt the poorly understood, internationally-orientated, demands to the local conditions.

Figure 3.8 combines the assessment guidelines used by Acosta et al (2014) with the original explanatory examples provided by Oliver (1991).

Overall, empirical evidence of Oliver's more confrontation strategies is rare. In a review of 53 articles where an institutional perspective was taken to study information technology related phenomena, other than acquiescence, Mignerat and Rivard (2015) only found one example where a different strategy was being followed or considered. This was another low confrontation strategy, that of avoidance, which they found to be present in eMarkets. However, they called for more research. They argued that greater diversity, beyond low confrontation strategies, is likely to exist for the implementation and adoption of information technology. My research will use Figure 3.8 to explore this matter at Waypoint A.

Strategic Response to Institutional Processes	Oliver (1991)	Acosta et al (2014)
Acquiescence	**Habit**: Following visible, taken-for-granted norms. **Imitate**: Mimicking institutional models. **Comply**: Obeying rules and accepting norms.	The practice is fully implemented. It has become part of the company's operating processes.
Compromise	**Balance**: Balancing the expectations of multiple constituents. **Pacify**: Placating and accommodating institutional elements. **Bargain**: Negotiating with institutional stakeholders.	The company feels the need to balance conflicting demands from multiple sources or between external pressures and internal objectives. The implementation is partial, but the company does not try to conceal it.
Avoidance	**Conceal**: Disguising non-conformity. **Buffer**: Loosening institutional attachments. **Escape**: Changing goals, activities, or domains.	Little, or no, implementation occurs. The company conceals the non-conformity.
Defiance	**Dismiss**: Ignoring explicit norms and values. **Challenge**: Contesting rules and requirements. **Attack**: Assaulting the sources of institutional pressure.	The company publically dismisses the practice or attacks the source. No implementation occurs.
Manipulation	**Co-opt**: Importing influential constituents. **Influence**: Shaping values and criteria. **Control**: Dominating institutional constituents and processes.	The company actively tries to change the content of the practice. The intended practice is not implemented.

Figure 3.8: Strategic responses to institutional processes

3.5 Studying progress at Waypoint B

Waypoint B is shown in Figure 3.2 and is set during the growth of results for the longer term (i.e. step 8 in the SD/DT process) and the embedding into routine business (i.e. step 9 in the SD/DT process). Here, I look to a fusion of institutional and organisational learning theory to study the SD/DT process for the following two reasons. Firstly, I wish to maintain continuity with institutional theory having used it at Waypoint A to account for supplier choice. Institutional theory has a strong track record of having been used for both SD and DT research (section 3.1). Secondly, I wish to build upon and respond to the organisational learning research which I covered in section 2.3, most notably: Lane (2001) and Knight (2002). Since their research, Haunschild and Chandler (2008) have coined the term "*institutional-level learning*" to describe the process which occurs when institutions change due to some learning experience. Few scholars have integrated these theories and advanced this particular research agenda. However, Chandler and Hwang (2015) developed a simplified model which I have synthesised in Figure 3.9. They call for empirical research to explore it.

		Stage of diffusion				
		Introductory	Emergent	Point of best practice becoming readily available to share	Intermediate	Institutionalised
Organisational adoption strategies	Local Imitation				**YES** Positive State (e.g. motivated by becoming more legitimate)	**YES** Neutral State (e.g. some motivated only by becoming less illegitimate)
	Local Reconfiguration		**YES**			
	Distant Imitation	**YES**				
	Distant Reconfiguration	**YES**				
		Note that the authors, Chandler and Hwang (2015), give a clear warning that their mapping is highly simplified and influenced by several contextual factors.				

Figure 3.9: Simplified model of diffusion and organisational adoption strategies

(synthesised from Chandler and Hwang, 2015)

The technology diffusion models from Geroski (2000) provide a further perspective to Figure 3.9 and suggest similar characteristics. The "*prohibit*" model has resonance with institutional theory and the drivers which I described in section 3.4 for Waypoint A. He explains that this model follows from the premise that "*different firms, with different goals and abilities, are likely to want to adopt the new technology at different times*". Pointing, amongst other things, to consideration of the fact that suppliers have choice. Also, the "*epidemic*" model has resonance with organisational learning theory and that which I am seeking to find evidence of at Waypoint B. He explains that this model follows from the premise that "*what limits the speed of usage is the lack of information available about the new technology, how to use it, and what it does.*"

The importance of the sharing of best practice is shown clearly by Chandler and Hwang (2015) in Figure 3.9. It is positioned as the key enabler to transition from an emergent to an intermediate stage of diffusion. The authors suggest that "*before the point of best-practice consensus is reached, adoption rates are likely to be low but will rise once standards are set*". This maps directly to the SD/DT process as it moves from step 7 to steps 8 and 9. Here, Figure 2.5 contains guideline 8.i (common vision and vocabulary) and guideline 9.ii (minimum standards and maturity models).

Hence, at Waypoint B, my research will search for evidence of best-practice sharing.

3.6   Research question, scope, and paradigm

My research paradigm is that of critical realist. Blaikie and Priest (2017) review a range of potential paradigms for social research. They argue that *"once preliminary work identifies the need to investigate a causal mechanism for an important regularity and, perhaps, suggests how a situation or practice may change as a result of what generates the regularity, then a critical realist inquiry is, prima facie, the obvious candidate"*.

The ontological domains of critical realism and institutional theory are interrelated and compatible (Wry, 2009). The following description from Scott (2014) conveys my approach. He explains the distinctive features of using institutional theory to study organisations over alternative approaches.

"Institutionalists eschew a totalistic or monolithic view of organisational and societal structures and processes …

Institutionalists emphasise that even innovative actions make use of pre-existing materials and enter into existing contexts which affect them and to which they must adjust …

Institutionalists insist on the importance of non-local, as well as local, forces shaping organisations …

Institutionalists have re-discovered the important role played by ideas, specifically, and symbolic elements, generally, in the functioning of organisations …

Institutionalists accord more attention to types of effects occurring over longer time periods…

Closely related to their concern with time, institutionalists also accord more attention to an examination of social mechanisms … interest in mechanisms directs attention away from questions regarding what happened to questions of how things happen …

Institutionalists embrace research designs that support attention to examining the interdependence of factors operating at multiple levels to affect the outcomes of interest."

The causal mechanism which my research is exploring can be summarised using the following format which was adapted from Easton (2000) and his critical realist case study into industrial networks:

An object = Extended Enterprise for which Rolls-Royce are the focal firm.

with structure = Hierarchy of firms (Figure 1.3).

possessing powers and liabilities = Derived from contextual factors (Figure 3.3).

under conditions = SD/DT process (Figure 2.5) used to initiate fieldwork.

will produce a change of events = Does the object move towards a Digital Enterprise?

Waypoints A and B are set to assess progress (sections 3.4/3.5).

Figure 3.10 consolidates the research question, scope, and gaps. Chapter 3 has identified and targeted a third research gap and, therefore, this is the final entry.

Research Question	Research Scope	Research Gaps
How to develop suppliers …	*The aerospace sector which has collaborative, adversarial, and ambivalent buyer/supplier relationships.*	Using SD to facilitate DT (Figure 2.2; CAPS, 2014; and Watts & Hahn, 1993)
within an Extended Enterprise …		Organisational learning in complex supplier networks (Lane, 2001)
towards a Digital Enterprise.		Operationalisation & measurement of absorptive capacity (Wijk et al, 2011; Roberts et al, 2012; and Lewandowska, 2015)

Figure 3.10: Summary of research question, scope, and gaps

3.7   Summary of key implications from this chapter

I have made the following contributions in chapter 3:

a) Established a theoretical framework for my research.

b) Identified contextual factors with the level of analysis spanning the network, dyad, and firm.

c) Developed a situational approach to measure the role of firms in new product development.

d) Developed a novel approach to operationalise and measure relative absorptive capacity using supplier scorecards.

e) Set two waypoints on the journey towards a Digital Enterprise using institutional and organisational learning theories.

f) Confirmed my research paradigm as critical realist.

Briefly, it is apt to mention the alternative research directions which I discounted. My scope (and funding) is concerned with supply chain management. I quickly found my interest drawn to the causal powers and institutional mechanism within an Extended (Digital) Enterprise. Therefore, I avoided paths which risked taking my research into the specialist domains of digital technology or pedagogy. Nevertheless, during the exploratory phase of my research, I contemplated placing more emphasis upon exploring the co-creation and diffusion of shared technical data standards and digital protocols. As explained in section 3.3.1, I wrestled with aspects of the specificity of digital systems and tools. However, I settled upon adding to the stimulus to resolve these matters rather than making a concerted attempt to advance them per se.

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METHODOLOGY

Explaining the design and execution of my research

Chapters 1 and 2 set the scene and synthesised process-steps for organisational change from literature. Chapter 3 constructed a theoretical framework for my research. It included contextual factors with which to characterise firms and waypoints at which to study choice, diffusion, and organisational adoption.

Now, chapter 4 describes the research methodology and how it is designed to develop and test the SD/DT process. This chapter is divided into six sections from 4.1 to 4.6. It begins by selecting action research, conducting a validity check, and taking special measures in response. Then, section 4.3 constructs the action research cycles, explains how they coalesce around a drumbeat of 21 workshops held over 3-years, and introduces my diverse study group of 24 firms. The triangulation strategy is described in section 4.4 whilst section 4.5 goes onto explain that transferability is a better concept to adopt than generalisation. Finally, section 4.6 summarises and draws out the key implications. A bullet-point executive summary is given overleaf for those who prefer this format.

Section 4.1:   **Action research (AR) is confirmed as my method**

- Case study research is a potential method to use instead of AR, but it is rejected because my researcher-object relation is interventionist (not observer).

- AR features strongly in one of the seminal works on interfirm network development (Chisholm, 1998). Also, more recent articles point to it being likely to lead to theoretical innovations and sustainable change in my research setting.

- AR has past precedence of being used for similar purposes to my own. There are calls for it to be used more.

- Validity check is passed for my application of AR, but ethical and researcher power issues are highlighted.

Section 4.2:   **Special measures are taken to address my complex positionality**

- Aspects of my insider/outsider positionality vary for my dealings within my own firm and for my dealings with other firms. My positionality is not uniform.

- Nevertheless, I am well supported by the staff and global structures at Rolls-Royce in working cross-culturally (Hofstede et al, 2010).

- Steering group is established to guide my research.

- Expert panel is established to provide independent specialist support.

Section 4.3:   **AR cycles are initiated using the 'background' SD/DT process**

- AR cycles of plan–act/observe–reflect are followed. They are initiated using the background version of the SD/DT process synthesised from literature in chapter 2.

- AR cycles coalesce around a drumbeat of 21 group-based workshops facilitated by the prime researcher and held at international locations from 2017Q1 to 2020Q1.

- A diverse study group of 24 firms is established.

Section 4.4:   **Triangulation strategy to compare absorptive capacity with supplier outcomes**

- Relative absorptive capacity is the only contextual factors to change over the duration of my research. It is measured quantitatively using supplier scorecards and the data is gathered independently of the prime researcher.

- Supplier outcomes are assessed against success criteria using mainly qualitative data which is gathered from various sources. The assessment is performed, somewhat independently, by the prime researcher and another member of staff.

- A response framework is constructed for supplier-side interviews to aid the discussion about "*What is your firms purpose in being on the SD/DT programme?*".

Section 4.5:   **Transferability is a better concept to adopt than generalisation of my results**

- Findings may be transferred from a sending to a receiving context (Lincoln and Guba, 1985).

Section 4.6:   **Summary of key implications from this chapter**

- Contributions from this chapter are shown listed.

4.1 Action research is confirmed as my method

Through the following sub-sections, I conclude that action research has the potential to answer my research question. It is well suited to my research situation, has past precedence of being used for similar purposes, and passes a validity check.

4.1.1 Action research is well suited to my setting

My research is work-based as explained in section 1.4. Costley et al (2010) list nine methodological frameworks which have been used for such research: phenomenological approaches, hermeneutics, grounded theory, action research, soft systems, survey-based research, ethnography, case study research, and bricolage. They explain that organisational change is at the heart of action research and, therefore, from this perspective it looks to be an obvious candidate. The alternative is case study research which is far more common in SD literature (Ahmed and Hendry, 2012). A comparison between the two methods is given by Karlsson (2016) which I have used to down-select action research as shown in Figure 4.1.

Action research can be more socially demanding on the researcher than case study research; however, I selected it in full knowledge of this. From my perspective, the pain is worth the gain. Also, researchers can become co-opted over time and lose a critical reflexive distance. I will address these points later in this chapter.

Words of support for action research come from multiple sources. In one of the seminal works on inter-organisational network development, Chisholm (1998) explains that "*using action research to create and maintain networks as learning systems emphasises a process of proactive engagement, not simply reactive adjustment*". Meehan et al (2016) argue for greater use to study purchasing and supply management, concluding that: "… *the depth and criticality of [action] research is likely to lead to theoretical innovations and sustainable change in organisational practice*". Coughlan and Coghlan (2016) give an example where they argue that the development of theory for a manufacturing strategy process, which was emergent through action research, would have been difficult to generate by other less intensive case-orientated methods. Also, according to Costley et al (2010), I am in a unique and privileged position as a work-based researcher with the opportunity to perform my research longitudinally. They cite such advantages as "*some work issues are beset with paradox and ambiguity, but an insider is often able to unravel and comprehend such intricacies and complications.*"

Perspective	Characteristics of case study research Karlsson (2016)	Characteristics of action research Karlsson (2016)	Reason why I selected action research (AR)
Research aim	Finding issues and variables; additions to theories	Finding out about change mechanisms and addressing a practical problem	Addressing a practical problem was a prerequisite set by my employer who funded my research. Nevertheless, a series of case studies could have been considered. However, through the literature review, my own interests in change mechanisms also grew.
Researcher-object relation	Observer	Interventionist	Overall, this aspect had the greatest impact upon my selection of AR. My employer, who funded my research, set as a prerequisite that there should be a 'progressive delivery of results' which pointed heavily towards a method with 'active' intervention.
Data	May be confidential	Probably confidential	High levels of commercial confidentiality restricted the consideration of a multiple case study approach, especially if they were beyond my own firm.
Analytical process	Within-case and across-case analysis and pattern finding	Continuing co-enquiry with the actors in the system	In addition to the above, AR was an attractive method because the process of co-enquiry offers the potential to improve both insights and buy-in.
Conclusions	Proposed variables and hypotheses	Impacts of interventions	Although there is only a sample of one for the Extended (Digital) Enterprise, this is far more defensible given it is a network compromising of a large number of actors with different contextual factors.
Generalisation	Can be limited	Hardly identifiable	Being company-funded, first and foremost, their own research needs had to be satisfied. See section 4.5 for how generalisation of the results is covered by transferability.

Figure 4.1: Key reasons why action research is selected over case study

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4.1.2 Action research has past precedence of being used for similar purposes

Action research is only marginally represented in supplier development, but there is some past precedence which I can draw upon. Coghlan and Coughlan (2008) describe the approach used in section 2.3.2 as an integration between action learning and action research (ALAR). Industrialists engaged in action learning whilst academics performed the action research. This resonates with some of my own experience. For example, Waterson et al (2001) describe their 21-month implementation study of PDM at Rolls-Royce as *"the research broadly falls within the tradition of action research, that is, our remit involved providing the company with recommendations for improvement and change, as well as satisfying a set of academic research questions."*

Looking more broadly, action research has long been used in the fields of digitisation, computing, and information technology. For example, Symon and Clegg (1991) based their study of CAD/CAM implementation upon it. Baskerville and Wood-Harper (1996) review the role of action research for developing and implementing information systems and, subsequently, Baskerville and Meyers (2004) provide six illustrative examples. Estruch et al (2008) use action research to study PLM in firms within a ceramic tile cluster which they call an Extended Enterprise. Furthermore, Pulkkinen et al (2018 and 2019) use action research over a 2-year period to develop a maturity model for what they call a Digital Extended Enterprise.

From a purchasing and supply chain management perspective, Momme and Hvolby (2002) use action research to study the global outsourcing of production for fabricated pressure vessels from a multi-national enterprise to external suppliers. They describe themselves as active participants as well as researchers. Their research delivers guidance on how to identify, evaluate, and select suppliers. Furthermore, Maestrini et al (2016) use action research to study the design and implementation of a supplier performance measurement system in the banking industry. They describe how buyer/supplier relationships are often *"messy"* and change over time. They reflect how action research helps to integrate diverse perspectives, providing mutually beneficial solutions.

To conclude, Ahmed and Hendry (2012) recommend that future research should *"use longitudinal case studies or action research to validate and determine measures of SD success in terms of short-term key performance indicators and measures of long-term relationship-specific and competitive advantage outcomes."*

4.1.3 Validity check is passed but highlights ethical and researcher power issues

Herr and Anderson (2015) offer a range of criteria for assessing action research taken from the perspective of the typical approach to researcher positionality i.e. from insider to outsider. However, mine cannot be positioned in this manner and I, therefore, found the work of Bartunek et al (2000) to be more appropriate. Here, they are specifically concerned with distinguishing between consultancy and manager-led action research in situations where managers or project leaders are directly involved in the research themselves. They identify issues and themes as a form of validity check by studying the characteristics and effectiveness of such research in diverse settings. There are eight themes and my test responses are summarised below:

Theme 1 from Bartunek et al (2000): The initial assignment to carry out work that leads to the action research project is likely to come from the manager's superiors and to be part of the manager's job description.

Test response for my research setting against theme 1: **TRUE**.

Theme 2 from Bartunek et al (2000): The other participants in the intervention are likely to be subordinates who need to buy-in to the change project.

Test response for my research setting against theme 2: **FALSE**. But, Bartunek et al (2000) also make reference to having decision-control and influence. This is **true** in my setting.

Theme 3 from Bartunek et al (2000): The intervention is likely to be aimed primarily at increased productivity.

Test response for my research setting against theme 3: **FALSE**. But, Bartunek et al (2000) also make reference to interventions which are aimed at improving processes. This is **true** for my setting.

Theme 4 from Bartunek et al (2000): Managers may find it helpful to constitute a consulting team to assist in the intervention.

Test response for my research setting against theme 4: **TRUE**. This was taken into account and incorporated into my research design. See section 4.2. Bartunek et al (2000) suggest that the team can either be assigned by the researcher themselves or by their superior.

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Theme 5 from Bartunek et al (2000): Data gathering can take place through a variety of formal and informal means.

Test response for my research setting against theme 5: TRUE.

Theme 6 from Bartunek et al (2000): Feedback sessions can be integrated into the work day or conducted separately.

Test response for my research setting against theme 6: TRUE.

Theme 7 from Bartunek et al (2000): The manager is likely to have a personal stake in the outcome of the intervention.

Test response for my research setting against theme 7: TRUE. This warrants further explanation. My research benefited greatly from the concept attributed to Senge (2006) of the "*learning organisation*". My employer, and in particular the series of industrial supervisors for my research, created an environment which helped to promote the philosophy that the outcome of my research was a learning outcome. The problem being addressed was challenging; therefore, there was no undercurrent of expectation to provide a quick fix. I was free to fail, learn, and try again.

Theme 8 from Bartunek et al (2000): The managers were all receiving training in action research while carrying out their interventions.

Test response for my research setting against theme 8: TRUE.

Hence, I conclude that it is valid for me to use action research.

However, scholars using action research in an interfirm setting (e.g. Coghlan and Coughlan, 2008; and Goduscheit et al, 2008) identify the need to address an array of ethical and researcher power issues. Costley et al (2010) give some mitigations for the "*response effect*" which may arise, but admit that these matters are often not easily dealt with by standard practice and protocols. The special measure which I took are described in section 4.2.

4.2   Special measures are taken to address my complex positionality

Robson and McCartan (2016) warn that "*someone attempting to carry out research into the situation in which they themselves are working … may find that the change aspects become virtually impossible to separate out from the research itself.*" But, they go onto explain that it is feasible to conduct credible research when faced with this dilemma. Like many others, they emphasise the need for strong academic supervision and good training. Despite conducting my research on a part-time basis, I was still very fortunate to have an empathetic and effective supervisory relationship with my academic supervisor. I quickly grew to realise it's importance and I am very indebted to him for it.

My biggest methodological concern was power asymmetry. As a well-known member of the buying firm, I foresaw that my research could encroach upon commercially sensitive matters with supplier firms. Also, I was dealing with different company and national cultures. Just within my own firm, my position in global headquarters meant that I was inevitably viewed as an outsider by the regional supplier and commodity management teams from whom I wished to gather data. Whilst many scholars recognise duality of role, they tend to base their research guidelines upon a rather static view of insider/outsider being maintained throughout the research process. Herr and Anderson (2015), for example, describe a continuum of six positionalities for action research. However, they do not include a non-uniform situation such as my own where the researcher must be aware of different aspects of their positionality within their own firm and in their dealings with other firms.

Nevertheless, scholars advocate reflexivity as a means by which power, position, and perceived status can be regularly questioned and, if appropriate, mitigated during a research programme (Kemmis and McTaggart, 2000; Coghlan and Brannick, 2014). As a part-time researcher operating from within my own firm, I sought to create enough space and distance to employ this. Costley et al (2010) recommend an ongoing process to help the researcher to clearly articulate their own perspective and to draw balance from others who provide alternative constructs and objectivity. I established a steering group and an expert panel to support me in doing it. However, before introducing them, I should first mention that I was also well supported in working cross-culturally (Hofstede et al, 2010). It was routine, for example, for me to be able to make arrangements for simultaneous English/Mandarin translation at events held in China. Furthermore, colleagues with local knowledge could help me to prepare interview scripts and to interpret the results afterwards.

4.2.1 A steering group is established to guide my research

The rationale for establishing my steering group came from a number of scholars. Coughlan and Coghlan (2002) call for action researchers to use them to help with governance and reflection on *"emergent learning"*. Lomax et al (1996) refer to them as *"validation meetings"* and Bartunek et al (2000) use them for *"consulting"*. Herr and Anderson (2015) go further and suggest they may serve the researcher as a kind of *"devil's advocate"*. I used mine for a mixture of these purposes depending upon where I was in the research programme and what issues were facing me at the time.

My steering group consisted entirely of staff from Rolls-Royce, although occasionally my academic supervisor made a guest appearance to supplement my regular one-to-one supervisions with him. Usually it was chaired by my line manager, co-ordinated with my industrial supplier, and attended by a cross-section of my peers and seniors from across the business. There were a number of major changes of personnel over the duration of my research which impacted the frequency that the steering group met and some of the consistency of thought. At its peak, particularly when I was wrestling with emergent findings, it met six-weekly. During less intensive periods, it was held on an ad hoc basis upon my request.

4.2.2 An expert panel is established to provide independent specialist support

I was aware of the risk of *"groupthink"* arising from all of the members of my steering group, and many of the specialists which I would draw upon for my research, coming from the same firm. Robson and McCartan (2016) warn of bias and gave me the impetus to establish an independent expert panel. I began by approaching academics or industrialists who had a background working knowledge of my firm. This broadened slightly to authors of key items of literature as I happened upon them. I never held group sessions, but instead sought their expert advice periodically on a one-to-one basis.

All of the five members of my expert panel have kindly agreed to be named in my thesis. They are: Professor James Aitken from the University of Surrey, Professor Du from Shanghai Jiao Tong University, Dr Greg Harris from Auburn University, Andy Page who is the CEO of Sharing in Growth, and Brad Farris who is a model-based enterprise (MBE) consultant. I am very grateful to them. They gave their time and expertise on a voluntary unpaid basis.

4.3   AR cycles are initiated using the 'background' SD/DT process

Costley et al (2010) describe the PDSA (plan-do-study-act) cycle as a form of action research (AR). This improvement cycle is familiar to me and the industrial setting of my research (Deming, 1986). Out of personal preference, I use the version from the action researcher planner by Kemmis and McTaggart (1988). This describes the AR iterative cycle as: plan, act and observe, and then reflect. Its origins are in pedagogy and I am attracted by the link to learning cycles (section 3.1.1a).

Coghlan and Brannick (2014) give options for conducting AR in a controlled manner for organisational development. However, they warn to expect change to occur "*messily and unpredictably*". The overarching framework which I use is attributed to Beckhard (1997). There is a present state (i.e. Extended Enterprise), desired future state (i.e. Digital Enterprise), and a series of AR cycles. The latter are summarised in Figure 4.2. The final (thesis) cycle captures and synthesises the learning based upon the experience gained throughout the core activity (Zuber-Skerritt and Perry, 2002).

AR cycle	Number of full iterations	Sequence and format
Basic	30+	• A full iteration of the basic AR cycle was performed for each of the 21 workshops (see Figure 4.3). • In addition, my field notes record others which blended in more "messily" over the duration of the research programme to study specific interventions. • Overall, in excess of 30 full iterations were performed.
Minor Core	9	• A full iteration of the minor core AR cycle was performed for each of the 9 steps in the SD/DT process. See Figure 1.7 and Figure 2.5.
Major Core	4	• A full iteration of the major core AR cycle was performed for groups of steps in the SD/DT process at points which coincided with workshop 2 (steps 1 to 4), workshop 7 (steps 5 to 7), workshop 14 (steps 3 to 9), and workshop 21 (steps 8 to 9). See Figure 1.7 and Figure 4.3.
Thesis	1	• This began in earnest after workshop 18 in order to inform the writing of my thesis, synthesis, and combined reflection on all of the above. See Figure 1.7 and Figure 4.3.

Figure 4.2: Summary of my action research (AR) cycles

The 'background' version of the SD/DT process from Figure 2.5 was used to initiate the AR cycles. These coalesced around workshops and, in total, twenty-one were held as shown in Figure 4.3. Each workshop was facilitated by the prime researcher, group based, and typically of two or three day's duration. Initially they were hosted by Rolls-Royce, then they moved to research centres (i.e. neutral venues), and by the fifth workshop they were being hosted by the suppliers at their own facilities. The final breakdown saw ten (48%) hosted by Rolls-Royce, eight (38%) hosted by suppliers, and three (14%) at research centres. Although most workshops were held in UK/Europe, there were three (14%) held in Asia Pacific and two (10%) held in the USA.

My inspiration for establishing and maintaining a regular drumbeat of workshops came from the CoI process (section 2.3.2) and specifically from Kaltoff et al (2007). They found that workshops helped to create a positive learning environment in which participant firms were open to sharing knowledge. During workshops, facilitation helped to keep focus and translate dialogue into concrete improvement projects. Between workshops, facilitation helped to deliver milestones and maintain momentum.

Chisholm (1998, 2000) also informed my design and delivery of the workshops. He used AR to study the development and maintenance of inter-organisational networks in the USA. I found three of his recommendations particularly useful: recognise that workshops are a significant part of the AR cycle requiring conscious design work beforehand; directly involve network members in the design and delivery of workshops; and hold debriefing sessions swiftly afterwards to reflect, question, and learn from happenings.

Figure 4.3 shows that I used the steering group (section 4.2.1) and expert panel (section 4.2.2) to help me to evaluate and reflect upon the workshops as part of the AR cycles. What is not shown, however, is the significant contribution made by many other members of staff from Rolls-Royce in the design and delivery of the workshops. It would have been impossible to conduct my research without them. Some scholars have suffered from delayed access to technical expertise and supporting documentation when studying the use and deployment of digital tools. Kennedy et al (2015), for example, highlight how such difficulties impacted their prioritisation of intervention over enquiry: action over research. I was very fortunate to experience no such problems.

Workshop Number	Date	Venue	Host	Number of firms present	Who evaluated and reflected with the prime researcher as part of the AR iterative cycles?
Start of the AR cycles with Step 1 in the SD/DT process (Strategic Review)					
1	2017 Q1	Asia Pacific	Rolls-Royce	93 in total 20 from Study Group	This was performed before and after the workshop with the academic supervisor
The output from workshop 1 was used to inform the next steps in the SD/DT process and the associated AR cycles which eventually led to Step 5 (Launch of Programme)					
2	2017 Q3	UK	Rolls-Royce	15 in total 14 from Study Group	This was performed before and after the workshop with Accenture Consultants (who had presented at the workshop)
The output from workshop 2 was used to inform the next steps in the SD/DT process and the associated AR cycles which eventually led to Step 7 (Delivery of Short Term Results)					
3	2017 Q4	UK	Research Centre	13 in total 13 from Study Group	This was performed before and after the workshop with a member of the research faculty (who had presented at the workshop)
4	2017 Q4	USA	Research Centre	9 in total 5 from Study Group	This was performed before and after the workshop with a member of the research faculty (who had presented at the workshop)
5	2018 Q1	UK	Supplier	7 in total 7 from Study Group	Over this 3-month period, evaluation and reflection was performed with the academic supervisor and the Steering Group
6	2018 Q1	UK	Rolls-Royce	97 in total 23 from Study Group	
7	2018 Q1	UK	Rolls-Royce	14 in total 14 from Study Group	
The output from the preceding workshops was used to inform the next steps in the SD/DT process and the associated AR cycles which eventually led to Step 8 (Growth of Results for the Longer Term)					
8	2018 Q2	Europe	Supplier	1 in total 1 from Study Group	Over this 6-month period, evaluation and reflection was performed with the academic supervisor and the Steering Group
9	2018 Q2	Europe	Supplier	12 in total 12 from Study Group	
10	2018 Q2	UK	Rolls-Royce	36 in total 0 from Study Group	
11	2018 Q4	Asia Pacific	Rolls-Royce	13 in total 3 from Study Group	This was performed before and after the workshop with Professor Du (Shanghai Jiao Tong University) who had presented at it
12	2018 Q4	Europe	Supplier	17 in total 17 from Study Group	This was performed before and after the workshop with Dr Greg Harris (Auburn University) who had presented at it
13	2019 Q1	UK	Rolls-Royce	18 in total 4 from Study Group	This was performed before and after the workshop with a representative from another OEM in the aerospace sector (Thales Group) who attended the workshop as an observer
14	2019 Q1	USA	Supplier	18 in total 14 from Study Group	This was performed before and after the workshop with Brad Farris (MBE consultant) who had presented at it
The output from the preceding workshops was used to inform the next steps in the SD/DT process and the associated AR cycles which eventually led to Step 9 (Embedding into Routine Business)					
15	2019 Q2	UK	Rolls-Royce	94 in total 23 from Study Group	This was performed before and after the workshop with Professor James Aitken (University of Surrey)
16	2019 Q2	UK	Rolls-Royce	13 in total 11 from Study Group	This was performed before and after the workshop with Professor James Aitken (University of Surrey)
17	2019 Q2	Asia Pacific	Supplier	38 in total 3 from Study Group	This was performed before and after the workshop with Professor Du (Shanghai Jiao Tong University) who had observed it
18	2019 Q4	Europe	Supplier	21 in total 17 from Study Group	This was performed before and after the workshop with the academic supervisor (who had attended the workshop as an observer)
19	2019 Q4	UK	Research Centre	16 in total 0 from Study Group	This was performed before and after the workshop with the academic supervisor
20	2020 Q1	Europe	Rolls-Royce	81 in total 19 from Study Group	This was performed before and after the workshop with Professor James Aitken (University of Surrey)
21	2020 Q1	Europe	Supplier	24 in total 18 from Study Group	This was performed before and after the workshop with Professor James Aitken (University of Surrey)

Figure 4.3: Drumbeat of workshops held throughout my research programme

The firms who attended the workshops came from the following groups: (a) the total population of ISS/SEP suppliers to whom steps 1 to 4 of the SD/DT process was applied on typically an annual basis; (b) the cohort of suppliers from [a] who joined the SD/DT programme; (c) other suppliers from beyond [a] who were co-opted onto the SD/DT programme (e.g. software vendors); and (d) other suppliers from beyond [a] who did not join the SD/DT programme but occasionally participated in activities (e.g. sub-tier suppliers). The suppliers referred to as (b) form the main study group for my research. There are twenty-four of them and, to protect their confidentiality, they have been renamed using the phonetic alphabet. To avoid confusion, the term Indigo is used (instead of India) and two terms (Mike and November) are omitted. Figure 4.4 shows their pattern of attendance.

	Workshop Number																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Alpha	●					●							●		●			●		●	●
Bravo	●	●	●			●	●		●			●	●	●	●	X		●		●	●
Charlie	●	●	●			●	●		X			●		X	●	●		●		●	X
Delta	●	●	●	●	●	●	●	●	●			●		●	●	●		●		●	●
Echo	●	●	●	●	●	●			●			●		●	●	●		●		●	●
Foxtrot	●	●	●	●	●	●	●		X			●		●	●	●		●		●	●
Golf	●	X	X		●	●	X		X			●		●	●	X		●		●	●
Hotel	●					●								●						●	●
Indigo	●	●	●			●	●		●			●		●	●	●		X		●	●
Juliet	●	●	●			●	●		●			●		●	●	●		●		●	●
Kilo	●	●	●	●	●	●	●		●			●		●	●	●		●		●	●
Lima	●	●	●			●	●		X			●		●	●	●		●		●	●
Oskar	●					●						●		●	●	●		●		●	●
Papa	●					●					●				●		●				
Quebec	●	●	●		●	●	●		●			●		●	●	●		●		●	●
Romeo	●	●	X			●	●		X					●							
Sierra						●								●						●	●
Tango	●	●	●			●	●		●			X	●	●						●	
Uniform	●					●					●	●		X	●		●	●			
Victor		●	●	●	●	●	●		●			●		●	●	X		●		●	●
Whiskey	●	X	X			●	●		X		●			●			●				
X-ray						●			●			●		X	●	●		●		●	●
Yankee	●	●	●			●	X		●			●		●	●	X		●		●	●
Zulu									●			●	●	●				●			●
Additional attendees at the workshops came from groups (a), (c) and (d) who are described in the main text above																					
(a)	●					●									●					●	
(c)		●												●		●		●			●
(d)				●						●	●		●				●		●		

Figure 4.4: Attendance at the workshops (● = attended; X = invited, but declined)

Figure 4.4 shows the pattern of attendance at the workshops to have been stable and quorate. Occasionally, firms were unable to attend. However, even at workshop 9 (which was transitionary with some firms departing and others joining after the first year) attendance never dropped below two-thirds of those invited.

The twenty-four firms in my main study group are very diverse. A summary of a few of their contextual factors from Figure 3.3 is given in Figure 4.5. My steering group judged them to be suitably representative of the firms within the Extended Enterprise. The only contextual factor which changed over the duration of my research was relative absorptive capacity. The measurement and triangulation of this is explained next in section 4.4.
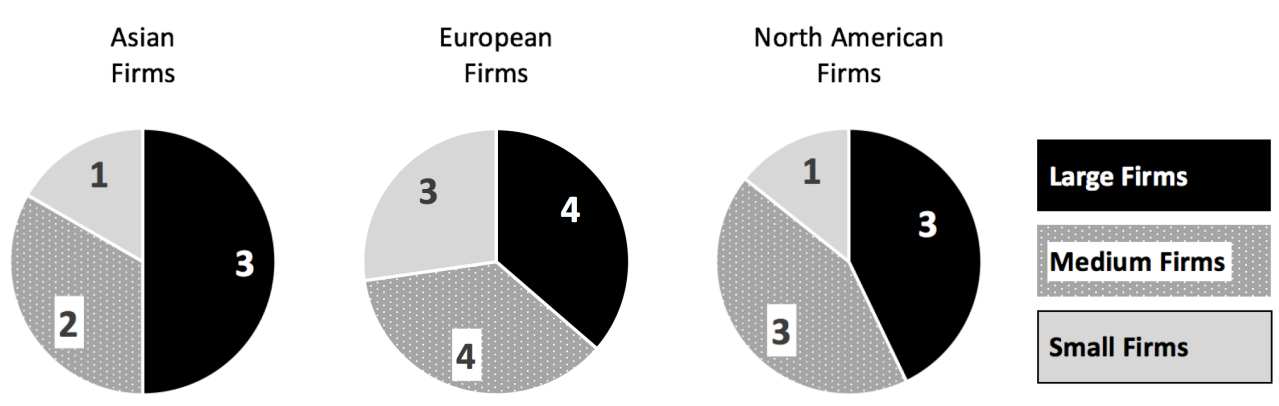
Figure 4.5: Summary of the twenty-four suppliers in my main study group

(The numbers within the pie-charts provide the geographical/size distribution of the 24 firms)

4.4 Triangulation to compare absorptive capacity to supplier outcomes

Key to my research is the operationalisation and measurement of relative absorptive capacity using supplier scorecards (section 3.3.2). This proved to be the only contextual factor which changed over my research timescales and, fortunately, quantitative data could be gathered using an existing well established process. However, an approach was required to triangulate in order to study if/how it pointed to the actual outcomes which were being observed in practice from the SD/DT process.

Constructing a triangulation strategy is subjective and "*the triangulatory investigator is left to search for a logical pattern*" (Jick, 1979). Two factors helped me. First, I had "*cases within a case*" (Gehman et al, 2018). My study group of suppliers are diverse as shown by Figure 4.5. Second, I had privileged access to both sides of the dyad (buyer and supplier) throughout three years of field work. My challenge was to mitigate the potential for bias arising from my positionality and prior knowledge. In total, I conducted nearly one hundred interviews (24 suppliers; 2 dyadic perspectives; and 2 phases i.e. towards the start and finish of my research). All interviews were semi-structured with questions sent to the interviewees in advance together with a research overview and an ethics statement. All interviews were recorded and transcribed afterwards.

Buyer-side interviews were conducted with the procurement and technical staff at Rolls-Royce who managed the operational and strategic relationship with the supplier. These interviews were typically held to coincide with the annual buyer/supplier business reviews for 2018 and 2019, namely: between workshops 9 and 12; and between workshops 17 and 18. In most cases, interviews were conducted face-to-face on company premises. When not, by phone. The interviews sought to track the buyer's perception of their suppliers' progress and outcomes through the SD/DT process. The buyers had previously baselined their desired outcomes when they selected their suppliers to participate in the SD/DT programme (step 4 in Figures 2.5 and 5.1).

Supplier-side interviews were conducted with the staff who managed their relationship with Rolls-Royce and/or who were nominated to attend the workshops in Figure 4.4. These interviews were conducted in conjunction with their first workshop attendance and, if they were invited to workshop 18, in the period after it and up to workshop 20. The first interview was typically conducted face-to-face at the suppliers' premises and the second by phone. The interviews sought to establish the suppliers' perspective of the value of the SD/DT process and their reasons for participation.

4.4.1 Interview design to explore Waypoints A and B

Waypoints A and B are shown in Figure 3.2. My contextual factors and theoretical framework are explained in sections 3.3, 3.4, and 3.5. My interviews needed to be designed to triangulate with relative absorptive capacity (as operationalised and measured through the supplier scorecards) and explore Waypoints A and B. In so doing, I was mindful of scholars, such as Robson and McCartan (2016), who argue that "*a focus solely on outcomes … does little to develop a cumulative understanding of complex social interventions.*"

My first phase of interviews studied supplier selection and on-boarding (i.e. up to step 7 of the SD/DT process); therefore, my second phase of interviews were those used to explore Waypoints A and B. They began with buyer-side interviews after workshop 17 (2019Q2) and finished with supplier-side interviews up to workshop 20 (2020Q1). By this time, many of those interviewed had a few years' familiarity with the SD/DT programme since it had been launched at workshop 2 (2017Q3). A full interview sequence (buyer, then supplier) was possible for 20 out of the 24 suppliers in the main study group. The suppliers who were not covered in full and are, therefore, not included for this aspect of the interview results in Chapter 6 are: Papa, Romeo, Tango, and Whiskey.

The buyer-side interviews were semi-structured and based upon the five strategic responses to institutional processes shown in Figure 3.8. The results were used to study Waypoint A. From the list of five strategic responses, most buyers selected "*acquiescence*" to describe how their supplier was responding. However, the buyers overwhelmingly stated that the codification and terminology from Figure 3.8 lacked sufficient granularity and carried too many negative connotations. They fed back that my questions were too "*negatively loaded*" (Robinson and Leonard, 2019).

Therefore, to prepare for the supplier-side interviews and the study of Waypoint B, I used MAXQDA qualitative analysis software to cluster and synthesise the terms which the buyers had used during their interviews (i.e. when they were elaborating upon those from Figure 3.8). The new terms which emerged are shown in Figure 4.6. The originating terms from Figure 3.8 are highlighted in bold and those which were synthesised from the buyers are listed alphabetically next to them. They are grouped on the basis of word association using the context in which they were raised by the buyers when discussing Figure 3.8. Some terms were raised by the buyers which went beyond this and, therefore, two new groups (D and F) are created for them in Figure 4.6.

	What is your firms purpose in being on the SD/DT programme?				
Group A	Acquiescing	Aligning	Complying	Integrating	Sponsoring
Group B	Avoiding	Buffering	Deferring	Observing	Waiting
Group C	Balancing	Compromising	Customising	Internalising	Translating
Group D	Benchmarking	Developing	Discovering	Learning	Understanding
Group E	Challenging	Defying	Deviating	Resisting	Testing
Group F	Contributing	Explaining	Sharing	Reciprocating	Teaching
Group G	Controlling	Influencing	Innovating	Manipulating	Steering

Figure 4.6: Response framework used for supplier-side interviews (Waypoint B)
(terms from Figure 3.8 are highlighted here in bold, but were not in bold when used for interview)

I based the construction of Figure 4.6 upon Foddy (1993) who categorises it as "*goal antecedents*" (i.e. I am trying to establish the respondents purpose in being on the SD/DT programme). His process of construction begins with mainly open questions (i.e. my buyer-side interviews) and then uses the resulting responses as a basis for more closed questions (i.e. my supplier-side interviews). I also used one of the means of measurement which he suggests (i.e. ranking scale: choose the first, then second, then third … most applicable response) and followed many of his probing and threat reducing strategies. I also used interview strategies from Kvale (2006) and Tayeb (2001) to deal with differences in values and practices across firms and to minimise my monopoly of interpretation.

Scholars use various terms to describe my response framework in Figure 4.6. For example: retrieval clues in Robinson and Leonard (2019), clarification features in Metzler et al (2015), example responses in Tourangeau et al (2014), word preferences in McPherson et al (2014), and word associations in Hovardas and Korfiatis (2006). They report advantages and disadvantages. Therefore, I pretested in accordance with Robinson and Leonard (2019). I used expert review and pilot testing in order to confirm that my construction had validity (i.e. "*one that measures what it is intended to measure*") and reliability (i.e. "*questions are answered consistently*"). I used Rolls-Royce staff in supplier-facing roles from around the world given the international nature of my research. No problems were identified and, hence, no adjustments were made to Figure 4.6 prior to its use.

The supplier-side interviews used to study Waypoint B were semi-structured and based upon the response framework in Figure 4.6. English was not the first language for some of those interviewed and they stated that they found the format helpful. Also, compared to the buyer-side interviews, it reduced the need for unstructured discussion to clarify and prevent misinterpretation. Furthermore, in Chapter 6, consistent themes will be shown to have carried through buyer/supplier interviews.

4.4.2 Success criteria for Waypoints A and B

Figure 3.2 shows how Waypoints A and B are milestones that I set to track the journey from an Extended Enterprise towards a Digital Enterprise. My theoretical framework for exploring them is described in sections 3.4 and 3.5 respectively. This section now explains how progress will be assessed in Chapter 6 in order for the results to be triangulated with relative absorptive capacity.

Waypoint A considers supplier choice using the five potential strategic responses to institutional processes defined by Oliver (1991). Therefore, as such, there is no success criteria used here. It is instead a means of categorisation for enquiry. The buyer reflects upon the level of engagement and progress being made by their supplier. Occasionally, this prompted a change (e.g. early exit for the supplier from the SD/DT programme or move to a local regional cluster) in which case the buyer discussed and agreed this with their supplier. Chapter 6 includes a summary of the results from Waypoint A and Chapter 5 describes how the SD/DT process was followed.

Waypoint B is that which is used in Chapter 6 to judge whether the SD/DT process has delivered successful, or unsuccessful, outcomes and to triangulate this with the measurement of relative absorptive capacity from the supplier scorecards. The success criteria for Waypoint B considers adoption and diffusion in accordance with section 3.5. Also, closer digital alignment emerged as an important consideration through the buyer-side interviews. The term that they prioritised alongside "*acquiescing*" in Figure 4.6 was "*aligning*". Previously during my research, it had been established that: (a) suppliers were typically well below the level of digital maturity perceived to be industry best practice, and (b) action and investment was being taken to improve but it was piecemeal and uncoordinated as a supply/value chain. See Figure 5.1, step 5, guideline 5.ii.

Figure 4.7 shows the six questions used to form the success criteria for Waypoint B. Each question must be answered in the positive in order for the outcome to be categorised in Chapter 6 as having been successful. Two persons performed the assessment independently as explained in the following paragraph. Nevertheless, it is predominately a buyer-side view of what constitutes success from the SD/DT process at Waypoint B on the journey towards a Digital Enterprise. From Figure 3.9, the instrument used for the sharing of best practice is the digital minimum standards and, therefore, they play an important role in the success criteria. Many of the questions in Figure 4.7 evolved during the buyer-side interviews and they were all eventually ratified by my steering group (section 4.2.1).

Paul Hacker, PhD thesis, University of Cambridge, May 2020

Buyer-side Interview (section 4.4.1)	Supplier-side Interview (section 4.4.1)	Digital Minimum Standards (section 5.2.3)	SD/DT Programme (chapter 5)
Q1: Is there evidence of closer digital alignment and an overall net benefit from having this supplier on the SD/DT programme?	**Q2:** Is there evidence of closer digital alignment and an overall net benefit from having this supplier on the SD/DT programme?	**Q3:** By the end of 2019, is the level of access to the training and awareness APP for the digital min standards commensurate with the firm's size and global footprint?	**Q6:** Has the firm made a tangible contribution to the SD/DT program?
This aspect of the success criteria predominately took a dyad-level view from the buyer's perspective. If the supplier had been sourced on the new UltraFan® engine project, then consideration was also given to their level of engagement and readiness for model-based definition. *Occasionally, during their interviews, buyer's also offered positive observations (no negatives were forthcoming) for the network-level.*	*This aspect of the success criteria took solely a firm-level view from the suppliers' perspective.*	*This aspect of the success criteria used access request data for the APP and compared it with the data used to assess the firm's contextual factors in section 3.3.*	*Examples may include: leading a working group; hosting a workshop; presenting at, or providing presentation material for, a cascade briefing to suppliers beyond the cohort; or volunteering for roles in the 2020 communities of practice.* *This aspect of the success criteria used the prime researchers field notes and took a cohort-level and a network-level perspective.*
		Q4: Were the digital minimum standards either achieved by the end of 2019 or a gap closure plan agreed for 2020? *This aspect of the success criteria used supporting data which was submitted in conjunction with the 2019Q4 supplier scorecard (technology). It was only applied to those suppliers who had one.*	
		Q5: Are key actions related to Q4 captured in the Tech Engagement Plan? *This aspect of the success criteria used the 2019Q4 supplier scorecard (technology). It was only applied to those suppliers who had one. But, if so, it gave an indication of prioritisation & escalation.*	

Figure 4.7: Success criteria used for Waypoint B comprises of six questions

NOTE: One of my prime references in section 2.2, Krause and Handfield (1999), remark about supplier development (SD) that "*the final objective is to achieve a globally aligned supplier network*".

The assessment of supplier outcomes at Waypoint B was performed in 2020Q1 using Figure 4.7 once all interviews were completed and transcribed. Two persons performed the assessment in order to balance the need for background knowledge with a level of independence. These persons were the prime researcher (Paul Hacker) and a graduate engineer (Liwei Lu) who was on a 6-month placement in the Supply Chain Collaboration department at Rolls-Royce up until the end of 2020Q1. My thanks to Liwei for his help, support, and meticulous approach.

The assessment was performed in the following manner:

- Liwei Lu collated all of the data from interview transcriptions and other sources.

- Paul Hacker used the data to assess outcomes for all suppliers using the success criteria given in Figure 4.7.

- Liwei Lu reviewed the data together with Paul Hacker's written-up rationale for the assessment of a sample of three suppliers (Alpha, Bravo, and Charlie).

- Liwei Lu clarified any points with Paul Hacker in order to familiarise himself with the application of the success criteria.

- Liwei Lu conducted the assessment by himself for the remaining twenty-one suppliers.

- Paul Hacker and Liwei Lu compared their full set of individual results, found very strong agreement, and after discussion around a few points (i.e. explaining acronyms, specialist technical terms, or historical references) reached consensus for all suppliers. The results are provided in Chapter 6.

4.5 Transferability is a better concept to adopt than generalisation

In reviewing the role of action research in the development and implementation of information systems, Baskerville and Wood-Harper (1996) describe it as being "*context-bound*". It is difficult to determine the cause of any given effect when it could be due to either: the environment, the researcher, and/or the methodology. Therefore, they argue that action research produces narrow learning, because each situation is unique and cannot be repeated. However, Greenwood and Levin (2006) refer to "*trans-contextual credibility*". They argue that action research does not generalise through abstraction and the loss of history and context. A conscious reflection must be made of similarities and differences.

Costley et al (2010) go onto explain the importance of "*situated-ness*" for work-based research. They advise researchers to be aware of, and to fully describe in their output, the organisation and the environment in which it operates. They warn against the assumption that any of the findings from one organisation can be applied to others. Nevertheless, by extension, the opposite is also true. We should not default to the position that it does not apply. Rather that we do not know, one way or the other.

Herr and Anderson (2015) review how to, carefully, tackle the application and read-across of results from action research. Amongst other approaches, they explain how to move away from the notion of the generalisation of findings to one of transferability. Findings can be transferred from a sending to a receiving context, in accordance with Lincoln and Guba (1985):

> *"If there is to be transferability, the burden of proof lies less with the original investigator than with the person seeking to make an application elsewhere. The original inquirer cannot know the sites to which transferability might be sought, but the appliers can and do. The best advice to give to anyone seeking to make a transfer is to accommodate empirical evidence about the contextual similarity; the responsibility of the original investigator ends in providing sufficient descriptive data to make such similarity judgements possible."*

In conclusion, generalisation of my results must be handled with caution. Transferability is a better concept to adopt than generalisation.

4.6   Summary of key implications from this chapter

I was presented with the following warning when I placed my action research into the classification system devised by Coghlan and Brannick (2014): *"Clearly the most difficult and demanding in terms of scale, complexity, conceptual, analytical and practical knowledge and skill."*

However, I consider myself to be extremely fortunate. Tayeb (2001) reflects upon the ideal design of research programmes and describes circumstances such as my own as *"feasible only for a select and fortunate few"*.

I have made the following contributions in chapter 4:

a) Selected action research as my method and passed a validity check.

b) Reflected upon my complex positionality and taken special measures to address it using a steering group and expert panel.

c) Coalesced action research cycles around a drumbeat of 21 workshops.

d) Introduced a diverse study group of 24 firms.

e) Constructed a response framework for supplier-side interviews to aid the discussion on their goal antecedents.

f) Established a triangulation strategy to compare relative absorptive capacity with supplier outcomes.

g) Identified that transferability is a better concept to adopt for my results than generalisation.

Chapter 5

RESULTS (part 1 of 2)

Description of the SD/DT process

Chapters 1 and 2 set the scene and synthesised process-steps for organisational change from literature. Chapter 3 constructed a theoretical framework. Chapter 4 described my action research methodology and how it develops and tests the SD/DT process through fieldwork.

Now, chapter 5 provides the first part of my empirical results in the form of a comprehensive description of the SD/DT process as output from my final (thesis) action research cycle. This chapter is divided into three sections from 5.1 to 5.3. It begins by introducing the process documentation. Then, section 5.2 explains the special interventions which are taken to facilitate the SD/DT process. Finally, section 5.3 summarises and draws out the key implications. A bullet-point executive summary is given overleaf for those who prefer this format.

Section 5.1: **Nine steps in the SD/DT process are output from thesis AR (action research) cycle**

- My research ended partway through step 9 of the SD/DT process at workshop 21. At this point, the cohort had 11 distinct projects of which: 6 were live, 3 were complete, 1 was cancelled, and 1 was in the hopper to be launched.

- 9 steps, 28 guidelines, and 4 categories of special intervention are output from my final, thesis, AR cycle for the SD/DT process.

- Each guideline is assessed for its criticality and the level of adherence that was achieved. Also captured are the key enablers and blockers.

- The documentation was first drafted by the prime researcher from field notes. It was then reviewed, individually, by 4 other team members. Changes were agreed to c.10% of the assessments and a few additional points were incorporated.

Section 5.2: **Four categories of special intervention are taken to facilitate the SD/DT process**

- Special interventions are taken to increase programme thickness. Software vendors are co-opted onto the programme. Also, a prize is awarded which gives access to specialist facilities/resources away from busy production environments.

- Special interventions are taken to organise the eclectic mix of firms and maintain programme cohesion. A regional cluster group is established in China, workshops are delivered for the UltraFan® project and commodity groups, and large firms are encouraged to host group workshops and/or have 1:1 events with the focal firm.

- Special interventions are taken to diffuse across the broader supply base. An engagement model is developed by the focal firm which comprises of 4 levels. The positioning of firms depends upon their strategic segmentation and their capability for self-improvement. Digital minimum standards are co-created and an APP is released for training and awareness purposes.

- Special interventions are taken to establish a dynamic model of membership. Communities of practice are introduced for 2020.

Section 5.3: **Summary of key implications from this chapter**

- Digital minimum standards are shown to have emerged as the instrument for sharing best practice in accordance with my theoretical framework in chapter 3. There is some indication of diffusion; however, it is still very early days. Therefore, this is identified as a topic for discussion in chapter 7.

- Overall, my research has made a positive business contribution. However, the SD/DT programme has undergone a long gestation (in business terms) and it remains uncertain how business value will continue to be extracted and to grow.

Paul Hacker, PhD thesis, University of Cambridge, May 2020

5.1 Nine steps in the SD/DT process are output from thesis AR cycle

Figure 5.1 gives the output from my final, thesis, action research cycle in the format of nine steps, twenty-eight guidelines, and four categories of special intervention for the SD/DT process. The guidelines are presented in accordance with two sources which I found to be particularly clear and informative when I came across them during my literature review. Firstly, Bokinge and Malmqvist (2012) who used a high, medium, and low scale of criticality/adherence to assess how well their PLM implementation guidelines had been followed. Secondly, Bessant (2004) who captured the key enablers and blockers from his case studies into supply chain learning. Furthermore, the guidelines in Figure 5.1 give a cross-reference to the special interventions which are described in section 5.2.

Figure 5.1 was first drafted by the prime researcher (Paul Hacker) from field notes which were taken and grouped against the initial baseline steps and guidelines (Figure 2.5). It was then passed to four members of the team from Rolls-Royce who had participated with the prime researcher in most, if not all, of the steps in the SD/DT process. These persons were: Ian Molyneux (Procurement Executive), Ben Buckton (Procurement Development Manager), James Buck (Chief of Digital Manufacturing), and Alistair Mateer (Digital Manufacturing Manager). Individually, they each reviewed and commented upon the first draft. There were no major disagreements and, therefore, it was possible to consolidate all inputs without the need for any further group reviews. Changes were agreed to approximately 10% (6 out of 56) of the high, medium, and low ratings for either adherence or criticality. Also, a few additional points or clarifications were incorporated into the narrative. My thanks to Ian, Ben, James, and Alistair for their tireless help and support throughout.

My research ended partway through step 9 of the SD/DT process at workshop 21. Therefore, for this final step in the process, the assessment of adherence to the guidelines is only based upon progress to date. When my research finished, there were 11 distinct projects and their status was as follows:

- 3 completed (digital minimum standard format 2019/2020, MBD go-live, and eFAIR diffusion).
- 1 cancelled before go-live (eDAR), but the learning had been passed onto a follow-on project.
- 4 at the capability development phase (DPEX, MBE supplier portal and digital interoperability, eFPA, and digital minimum standard format 2021).
- 2 at the discovery phase (commodity twin and production twin).
- 1 awaiting launch in the project hopper (value proposition for the Digital Enterprise).

SD/DT step 1: Strategic review

SD/DT step 1 (from Figure 2.5)	Results from the AR cycles (see Section 4.3 for an explanation of how the AR cycles were initiated and run)
1.i. Strategy for DT cuts across various other strategies at the same time and, therefore, complex coordination efforts may be needed.	**How:** Step 1 of the SD/DT process was initially performed in the period up to, including, and shortly after workshop 1. However, the PhD research programme helped to keep it live thereafter. The learning school approach to strategy formulation was followed (Mintzberg et al, 2009). The scope was aimed at the fourth level, business network redesign, in the series of IT-related transformations defined by Morton (1991).
	Special Interventions: None taken.
	Adherence: This guideline was satisfied to a HIGH degree.
	Enablers: Someone to spend the time coordinating efforts who has a high level of declarative and procedural prior knowledge (see Figure 1.6).
	Blockers: Strategy formation was emergent in line with the learning school approach (Mintzberg et al, 2009) and required prior knowledge (see above) and a good network.
	Criticality: This guideline is of HIGH criticality to the success of the SD/DT process.
1.ii. Build contingency planning and funding for technological breakthroughs into the strategic plan for change.	**How:** During the exploratory phase up to workshop 1, vision documents were traced back to 1994 and 2005 for Electronic Product Definition and PLM supplier collaboration respectively. Interviews with those involved established that shortfalls in functionality and funding plagued these programmes. Aspects of which continue.
	Special Interventions: None taken.
	Adherence: This guideline was satisfied to a LOW degree.
	Enablers: A core team with perseverance and resilience (see 2.ii).
	Blockers: An unprecedented set of circumstances placed severe financial pressure on the focal firm during the period of research. Funding levels were reduced and all expenditure was subject to strict review. Nevertheless, the criticality of this guideline has been set at medium to reflect that prioritisation is possible (i.e. the 80/20 rule).
	Criticality: This guideline is of MEDIUM criticality to the success of the SD/DT process.
1.iii. Map and include in scope the total, global, supply base.	**How:** The application of the SD/DT process was built upon nearly twenty years of successful operation as an Extended Enterprise (see Section 1.2.2). The supply base was, therefore, fully mapped and segmented prior to the launch of the programme.
	Special Interventions: None taken.
	Adherence: This guideline was satisfied to a HIGH degree.
	Enablers: A mature and well known, albeit complex, supply base (see Figure 1.3).
	Blockers: With the benefit of hindsight, it would have helped to have mapped the supply base earlier using the lean engagement approach (see Figure 5.2).
	Criticality: This guideline is of HIGH criticality to the success of the SD/DT process.
1.iv. Deploy other supply base management practices ahead of SD/SA.	**How:** In addition to the baseline provided through 1.iii. the SD process had been used previously for lean, although it's use had been somewhat dormant over recent years.
	Special Interventions: None taken.
	Adherence: This guideline was satisfied to a HIGH degree.
	Enablers: An established infrastructure of supplier scorecards and engagement plans containing strategic, as well as operational, attributes (see Section 3.3.2).
	Blockers: A relatively poor perception of supplier development (i.e. cost-cutting); therefore, this term was avoided and others were used such as Focus Group.
	Criticality: This guideline is of HIGH criticality to the success of the SD/DT process.
Any new guidelines which emerged from the AR cycles.	None emerged.

Figure 5.1: Steps and guidelines for the SD/DT process (page 1 of 10)

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SD/DT step 2 (from Figure 2.5)	Results from the AR cycles (see Section 4.3 for an explanation of how the AR cycles were initiated and run)
2.i. Use methodology which integrates business processes and co-evolves digital enterprise systems together with the supply base.	**How:** The methodology followed the SD/DT process which is contained herein. It had to be created and was, therefore, not available at the time of workshop 1. However, during workshop 1, c.100 of the focal firm's top suppliers were asked the question "How do we become more digital?" in small groups in open brainstorm sessions. They confirmed the importance of this subject and pointed to some potential solutions. This subsequently helped with buy-in and provided a solid platform upon which to take the next step in the SD/DT process.
	Special Interventions: None taken.
	Adherence: This guideline was satisfied to a HIGH degree.
	Enablers: Approximately 6 months prior to workshop 1, in response to another 'wicked problem' to drive to Zero Defects, a forum similar to a Supplier Association was established. This started as a potentially one-off Focus Group, but exceeded expectations and morphed into a collection of ongoing Working Groups. As a collaborative structure, this laid the foundations for that which was then used and built upon by the SD/DT process.
	Blockers: Without knowing the SD/DT process upfront, the planning horizon for the action research was somewhat limited and its use started where there was most interest and not necessarily where there was most need. The digital enterprise systems in Engineering (e.g. MBE) tended to dominate over those in Procurement (e.g. e-Sourcing) and Planning (e.g. ERP).
	Criticality: This guideline is of HIGH criticality to the success of the SD/DT process.
2.ii. Gain the support of top management, build a cross-functional team, and train the team in the methodology.	**How:** The support of top management was gained at an early stage through their sponsorship of the PhD research programme. Furthermore, it was reinforced by the output from workshop 1 which confirmed there was a gap to be filled and that the supply base wished to actively participate. In accordance with Kanter (1999), a Network Champion and a Collaboration Resource Team were established. Existing forums were used for governance. However, the methodology (i.e. SD/DT process) was emergent, because it was being created as a result of 'action research'. The team were, therefore, untrained in SD/DT; although, as an experienced group of industrialists, they were very familiar with the approach of 'learning by doing'.
	Special Interventions: None taken.
	Adherence: This guideline was satisfied to a HIGH degree.
	Enablers: The timing of the first iteration of step 2 coincided with a push from the Procurement and Engineering Directors at the focal firm to bring their functions closer together. Also, as well as this being done at the sector-level, they were also asked to sponsor for the whole corporation.
	Blockers: The prime researcher took the role of Network Champion (Kanter, 1999), but was unable to establish a successor despite a few attempts which were made over the coming years. Anticipating and planning for this could have been performed better here. It becomes more of a blocker later in the SD/DT process (see 6.i).
	Criticality: This guideline is of HIGH criticality to the success of the SD/DT process.
2.iii. Make an informed decision on if/when to launch Supplier Association(s) and set a clear remit for JAD (Joint Application Dev) and/or USER groups.	**How:** See 2.i. in that a recent precedent had been set for a forum similar to a Supplier Association and, therefore, a well informed decision was able to be made on whether to commit the time/effort/expectation necessary to run another one. However, the added dimension of defining the role which members might play in the requirements capture, development, and user acceptance testing of digital enterprise systems was unanticipated and emerged over time.
	Special Interventions: None taken.
	Adherence: This guideline was satisfied to a MEDIUM degree.
	Enablers: There was a pull for this from workshop 1.
	Blockers: Still now, after 3 years' experience, it is not straight-forward facilitating how suppliers will play a strong and active role in the requirements capture, development, and user acceptance testing of digital enterprise systems. The challenges range from logistical to cultural to motivational. Matters are not helped by many Execs lacking a sufficient knowledge of digital.
	Criticality: This guideline is of MEDIUM criticality to the success of the SD/DT process.
Any new guidelines which emerged from the AR cycles.	None emerged.

Figure 5.1: Steps and guidelines for the SD/DT process (page 2 of 10)

SD/DT step 3: Evaluation of suppliers

SD/DT step 3 (from Figure 2.5)	Results from the AR cycles (see Section 4.3 for an explanation of how the AR cycles were initiated and run)
3.i. Evaluation is likely to need to cover multiple factors.	**How:** Evaluation was aided by the supply base already being mapped and segmented (see 1.iii) and data being readily available from supplier scorecards and engagement plans which contained strategic, as well as operational, attributes (see 1.iv). Therefore, the scope of potential suppliers to consider was well controlled and evaluation was initially performed by survey (see 3.ii). Shortlisting was then followed by internal discussion at the focal firm with the operational and strategic management teams who interfaced with the suppliers. For shortlisting, the dominant factor in the evaluation was whether the supplier was likely to demonstrate a supportive and collaborative spirit to the launch of this new initiative. Secondary factors were their current level of digital maturity and the perceived need for this to be improved, or shared to help others, for operational performance or strategic capability development purposes.
	Special Interventions: None taken.
	Adherence: This guideline was satisfied to a HIGH degree.
	Enablers: An established infrastructure of supplier scorecards and engagement plans containing strategic, as well as operational, attributes (see Section 3.2.2).
	Blockers: At this point in time, the understanding of the value proposition was still very immature which made the evaluation less sophisticated than it otherwise may have been. Also, it contributed to the evaluation only being performed with incumbent suppliers.
	Criticality: This guideline is of HIGH criticality to the success of the SD/DT process.
3.ii. Evaluating suppliers for digital maturity/needs will not be straight-forward, but spot-check surveys can help to highlight broader industry trends including areas of common interest and digital non-interoperability.	**How:** To create a survey, the team (see 2.ii) drew in additional subject matter experts in enterprise processes and their associated digital systems/tools. The survey had six sections covering: company details; design systems; manufacturing systems; purchasing systems; supply chain planning systems; and organisational infrastructure. Up to twelve open and closed questions, per section, were posed in the survey with the aim of evaluating the suppliers' current status, aspirational position, and suggested areas for collaboration. A maturity-based scale was used in accordance with Moultrie et al (2007) which, recognising the rapidly changing nature of digital technologies, set the second highest level of maturity as being that which the focal firm believed to be 'industry best practice' at that point in time. The survey was in electronic format and was distributed to all of those who attended workshop 1. There was a period of approximately two months to complete, return, evaluate and down-select before workshop 2. The response rate to the survey was 49%. This was judged to be satisfactory against the benchmark of 35-40% set by Baruch and Holtom (2008) for organisational-level surveys of a cross-functional nature which require a single consolidated response.
	Special Interventions: Exploratory studies leading up to workshop 1 were centred around new product development (NPD). Customer policy such as that from the DoD (2018) was yet to be published, but the writing was on the wall. Although not performed here, supplier selection and/or capability development for NPD could have been part of the evaluation, and a special intervention which is more centred around it is described later in section 5.2.2.
	Adherence: This guideline was satisfied to a HIGH degree.
	Enablers: New product development at the time was beginning to use the digital capability assessment tool (NIST, 2016). This helped to inform the survey. Also, the group of twelve suppliers which had been brought together to work on Zero Defects (see 2.i) were asked to help by trialling the survey in advance. Their feedback was very valuable and was incorporated before the survey was distributed more widely.
	Blockers: Digital transformation is a complex and diverse subject. Getting to the right person(s) from which to gather accurate data is not easy, especially given other factors such as: different company sizes, organisational structures, and language barriers. Allow plenty of time to do so.
	Criticality: This guideline is of MEDIUM criticality to the success of the SD/DT process.
Any new guidelines which emerged from the AR cycles.	A point of timing and emphasis, as opposed to a new guideline, is the importance of creating a common vision and vocabulary at the earliest opportunity. This is covered later as guideline 8.i. It takes time. However, without it, those who do not have a full grasp of the subject are prone to misuse/misunderstand the many specialist terms and buzzwords involved.

Figure 5.1: Steps and guidelines for the SD/DT process (page 3 of 10)

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SD/DT step 4: Selection of suppliers

SD/DT step 4 (from Figure 2.5)	Results from the AR cycles (see Section 4.3 for an explanation of how the AR cycles were initiated and run)
4.i. The selection criteria must be robust.	**How:** The survey (see 3.ii) asked whether the supplier wished to participate in what became workshop 2 in order to follow-up on the topics which they had raised in the survey and in workshop 1 (see 2.i). The only condition was for them to have completed and returned their survey. However, it was explained that the number of participants was restricted; therefore, a dynamic model of membership was envisaged which would allow those who were unsuccessful to participate at future events (see Section 5.2.4). From the suppliers, there were no requests for further clarification nor complaints about not being selected at launch. From the focal firm, there were a few cases where there were either too many, or too few, suppliers nominated from a given region or commodity group to achieve the desired mix (see 4.ii). These matters were readily resolved through discussion.
	Special Interventions: Dynamic membership (de-selection & exit) is described in Section 5.2.4.
	Adherence: This guideline was satisfied to a HIGH degree.
	Enablers: A mature and well known, albeit complex, supply base (see Figure 1.3).
	Blockers: None identified.
	Criticality: This guideline is of MEDIUM criticality to the success of the SD/DT process.
4.ii. Plan the mix including different capabilities for different purposes.	**How:** A mix was sought which gave a representative cross-section of the supply base. Some of the contextual factors from Figure 3.3 were used and mapping, such as that in Figure 4.5, confirmed that a suitably representative cross-section had been achieved. Careful consideration was given to whether to include direct competitors, but this was not off limits. See 6.v.
	Special Interventions: Interfirm relations were assumed to be agnostic of digital systems/tools (see Section 3.3.1); therefore, this was not used as such in the selection. However, a special intervention emerged over time which sought to leverage the collective power of the supply base (see Section 5.2.1). By chance, larger suppliers who were selected used a myriad of products from the dominant software vendors which helped to give us more leverage with them.
	Adherence: This guideline was satisfied to a MEDIUM degree.
	Enablers: There was no shortage of interested suppliers to select from and we were over-subscribed. This is a testament to the previous steps of the SD/DT process.
	Blockers: Top-down, gentle, encouragement was required in a few cases for the non-Western suppliers. Global events run by the focal firm had a history of being dominated towards Western preferences, such as: the time zones for WebEx, the locations for face-to-face meetings, English as the main language for discussion, and the attitudes/approaches to sharing best practice.
	Criticality: This guideline is of HIGH criticality to the success of the SD/DT process.
4.iii. If considering the launch of a Supplier Association, do so with a relatively small membership or perhaps use New Product Development as an alternative.	**How:** Workshop 2 was in effect the launch of a themed, global, Supplier Association. Although, it was called a Focus Group in order to avoid any negative connotations and to use a title which remained consistent with other forums being used by the focal firm at the time. The target set for the number of members was twelve; however, this was permitted to grow somewhat surreptitiously to sixteen. With relatively short notice for international travel, fourteen suppliers from the main study group were available to attend workshop 2.
	Special Interventions: Other options for how to group and distribute an eclectic mix of suppliers, and the respective advantages and disadvantages of each option, became clearer over time. This is explained in Section 5.2.2.
	Adherence: This guideline was satisfied to a MEDIUM degree.
	Enablers: A member of the focal firm had first-hand experience of Supplier Associations from having previously worked for Toyota (see, for example, Morgan and Liker, 2006). He was interviewed by the prime researcher in order to gather his insights and lessons learnt. His in-depth knowledge of the similarities and differences in buyer/supplier relationships between both sectors (automotive versus aerospace) was helpful in defining the scope and vision.
	Blockers: This was a period of discovery and, with the knowledge now gained, it would have been even better if a range of other interplaying options were considered. See Section 5.2.2.
	Criticality: This guideline is of MEDIUM criticality to the success of the SD/DT process.
Any new guidelines which emerged from the AR cycles.	None emerged.

Figure 5.1: Steps and guidelines for the SD/DT process (page 4 of 10)

SD/DT step 5: Launch of programme

SD/DT step 5 (from Figure 2.5)	Results from the AR cycles (see Section 4.3 for an explanation of how the AR cycles were initiated and run)
5.i. Use the power of the voice of the customer.	**How:** The previous steps in the SD/DT process had led up to, and signposted, the launch event (workshop 2). Therefore, it carried more gravitas with the suppliers, because it was clearly important to the seniors of the focal firm. Both the Procurement and Engineering Directors were seen to be taking a strong personal interest. An end customer (Airline) had also attended workshop 1 and had been very pointed about the need to become more efficient and reduce costs. At the time, exploring opportunities through digital transformation seemed to be high on everyone's agenda.
	Special Interventions: None taken.
	Adherence: This guideline was satisfied to a `HIGH` degree.
	Enablers: In terms of the life cycle of digital transformation as an aid to business improvement, the timing was good for the launch of this particular programme. The period of hype was diminishing, but glimpses of the potential value proposition remained. Funds were available for investment and the launch of this programme offered the potential to do so more wisely whilst posing no tangible risk.
	Blockers: None identified.
	Criticality: This guideline is of `HIGH` criticality to the success of the SD/DT process.
5.ii. Break the stereotypes to inspire and avoid apathy.	**How:** Four aspects were considered with a view to inspiring and engaging the launch participants: venue; content and format; guest speakers; and key messages. Firstly, the venue was unconventional compared to the normal standards used by the focal firm with its suppliers. The workshop was held in the recently installed Innovation Lab at one of the focal firm's main sites. The facilities included very large touchscreens with soft seating, breakout areas, and digital demonstrators. Secondly, the agenda for the day's workshop covered both the 'hard' technology and the 'soft' people aspects of digital transformation. A mixture of presentation and discussion formats were used and suppliers brought some of their own case studies to share with the group. Thirdly, the guest speaker was from Accenture Consultants who had been working with the World Economic Forum on the Digital Transformation Initiative since 2015. This helped to broaden the perspective and to put the programme into context. Finally, the key messages at the launch event were informed by the previous steps in the SD/DT process and, therefore, this started to create a sense of momentum (i.e. taking action as opposed to being seen as a talking shop). An expectation was set for capturing the actions into themed groups and arranging a follow-up. The key messages at the launch event were extracted from the results to the survey (see 3.ii) and these revealed that: suppliers were typically well below the level of digital maturity perceived to be industry best practice; action and investment was being taken to improve but it was piecemeal and uncoordinated as a supply/value chain; and this programme could help to improve our collective position. Also, the 'focal firm knows best' stereotype was erased, or at least diminished, through the launch event. The team mantra started to emerge of "learning together" and feeling our way together through the "digital fog".
	Special Interventions: None taken.
	Adherence: This guideline was satisfied to a `HIGH` degree.
	Enablers: None of the suppliers' other customers were launching a programme such as this at the time, nor since, to the knowledge of the prime researcher (as informed by supplier interviews). Therefore, this benefited the programme in that it was seen as being new and pioneering.
	Blockers: None identified.
	Criticality: This guideline is of `HIGH` criticality to the success of the SD/DT process.
Any new guidelines which emerged from the AR cycles.	None emerged.

Figure 5.1: Steps and guidelines for the SD/DT process (page 5 of 10)

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SD/DT step 6: Operation and support of programme

SD/DT step 6 (from Figure 2.5)	Results from the AR cycles (see Section 4.3 for an explanation of how the AR cycles were initiated and run)
6.i. Establish and maintain a backbone support organisation and, as appropriate, draw in expertise from third parties.	**How:** The Core Resource Team ebbed and flowed, but the prime researcher remained as the Network Champion throughout (i.e. approx. 3 years). Continuity helps, but succession planning has been inadequate. See 2.ii. There is a risk of the programme being overly associated with a single individual which may hinder its future operation if/when personnel are changed. The use of third parties has been gradual and controlled. Such an approach is recommended. However, overall (as first noted in 2.i), it has continued to prove harder to engage with other functions beyond Engineering.
	Special Interventions: Careful consideration was given to the timing and the role of third parties. This is explained in Section 5.2.1.
	Adherence: This guideline was satisfied to a `LOW` degree. But this varied across the functions and the low assessment is because not all became as fully engaged as desired.
	Enablers: A strong network existed within the focal firm (called the Chiefs of Digital Manufacturing) which quickly embraced the programme and helped to support it. Also, a rolling sequence of placements on the internship and graduate training scheme was established at the focal firm. Under the direction of the Network Champion, this resource proved to be very valuable in maintaining the momentum of the programme.
	Blockers: Budgetary planning was limited for the backbone support organisation and a strong reliance was placed upon discretionary effort.
	Criticality: This guideline is of `HIGH` criticality to the success of the SD/DT process.
6.ii. The operating model can be flexible, but agreeing guiding principles and using project charters may help with communication and engagement. Maintain a balance between top-down goal setting in combination with bottom-up learning by doing. Use events with all suppliers in attendance to ensure that the same message is being given to all at once.	**How:** The participating suppliers were doing so on a voluntary basis at their own cost and, therefore, a balance had to be maintained with other business priorities if/when they arose. Different contextual factors played a role here. For example, smaller firms were less able to ring-fence resources or to allow them to travel internationally at short notice. The drumbeat of workshops provided the overall framework for the programme; however, most action only tended to coalesce around them. Attempts were made annually to revisit and refresh the equivalent of the project portfolio and work breakdown structure. At workshop 3, looking towards 2018, a series of Working Groups were formed. After workshop 12, looking towards 2019, a series of Project Charters were drafted. After workshop 18, looking towards 2020, a series of Communities of Practice were proposed. The latter is covered in more detail in 6.iv. Workshops 6, 15 and 20 were used to diffuse the key messages into the broader supply base on an annual basis in 2018, 2019 and 2020 respectively.
	Special Interventions: By workshop 9, it was clear that a special intervention was necessary for those who struggled to communicate in English. Also, around this time, other permutations to the operating model (e.g. 1:1's with the larger suppliers on the programme) started to be explored. These are explained in Section 5.2.2.
	Adherence: This guideline was satisfied to a `HIGH` degree.
	Enablers: The rigour and nature of the PhD research programme resulted in more frequent and open discussion about the operation of the programme than would have otherwise been the norm. Feedback was seen to be welcome and to be acted upon.
	Blockers: Relying heavily upon goodwill, without a unifying funding stream (e.g. neither new product development nor government funded research programme), meant that expectations were not always aligned. This was exasperated by the different contextual factors including the global dispersion and the varying levels of digital maturity.
	Criticality: This guideline is of `HIGH` criticality to the success of the SD/DT process.
6.iii. Promote the culture of a learning organisation and establish a network of change agents.	**How:** The "learning together" mantra took hold strongly from the start (see 5.ii). However, how specifically this related to the role of the participants who were sent by their firms to the workshops was left undefined and open to interpretation. The term "change agents" was first used explicitly at workshop 14 where an exercise was performed to explore what this meant and how the role should be discharged … *CONTINUED ON THE NEXT PAGE*

Figure 5.1: Steps and guidelines for the SD/DT process (page 6 of 10)

	… This exposed a number of gaps where participants were struggling to share the key messages from the workshops back into their own organisations. In addition to following-up thereafter on a 1:1 basis, a role model for a "change agent" was invited to share their experiences at a subsequent workshop (number 18).
	Special Interventions: On occasion, encouraging suppliers (and particularly the larger firms) to host a workshop gave their "change agent" a boost. See Section 5.2.2. Also, the operating model of the 2020 CoP helped to further clarify roles. See Section 5.2.4.
	Adherence: This guideline was satisfied to a MEDIUM degree.
	Enablers: The sponsorship and use of a PhD research programme helped to send a strongly positive message about being open to learning. No hostilities were ever encountered; but, perhaps it neutralised any potential concerns and provided a safer route into what may have otherwise been more sensitive matters.
	Blockers: Challenges were under-estimated on how the participants at the workshops were to disseminate and act as a conduit back into their own organisations. Also, participants came from a mixture of technical and non-technical roles. Digital transformation is a complex subject which requires significant coordination. With the benefit of hindsight, this should have been a stronger theme from launch.
	Criticality: This guideline is of HIGH criticality to the success of the SD/DT process.
6.iv. Communities of practice may help to facilitate physical and virtual modes of collective learning.	**How:** The first attempt at using an electronic tool to support networking, sharing best practice, and problem solving was made at workshop 6. One of the suppliers on the programme volunteered to source, host, and administer an electronic tool. However, despite it being user-friendly, it was rarely used. Feedback suggested that this was because of two reasons. Firstly, suitably close working relationships were too early to have formed and did not extend to all of the digital subject matter experts within each firm. Secondly, the format used for electronic communication and collaboration, which was similar to social media, seemed to be more suited for intra- rather than inter-organisational purposes. About a year later, following workshop 18, a more structured approach to communities of practice was suggested for 2020. This received strong support and a survey was distributed by the focal firm to match topics to interested parties. The topics/parties, and the overall approach for 2020, received ratification at workshop 21 which is where the period of study has ended.
	Special Interventions: The operating model for the 2020 CoP is shown in Section 5.2.4.
	Adherence: This guideline was satisfied to a MEDIUM degree.
	Enablers: None identified.
	Blockers: Language and accessibility, when working globally, together with the protection of intellectual property when working inter-organisationally.
	Criticality: This guideline is of MEDIUM criticality to the success of the SD/DT process.
6.v. Set policy, and keep it under review, for sharing through either open-access or non-disclosure.	**How:** During the initial workshops, policy was established by mutual agreement that whatever was shared was done so on the basis of it being open-access. On very few occasions, when it proved necessary because competing suppliers or foreign nationals were present, access became more limited. A non-disclosure agreement with the suppliers on the programme was never used individually nor as a group; however, it was used with guests e.g. Consultancy Firms. Existing members were given a courtesy briefing when new suppliers joined the programme who were their direct competitors; however, decision-rights on membership were always retained by the focal firm.
	Special Interventions: None taken.
	Adherence: This guideline was satisfied to a MEDIUM degree.
	Enablers: The Network Champion became suitably trusted by all parties to be able to facilitate a hub-and-spoke model for matters where more intimacy was desired.
	Blockers: The global diversity and competitive mix of the group most probably exaggerated the already different attitudes to sharing and protecting data.
	Criticality: This guideline is of HIGH criticality to the success of the SD/DT process.
Any new guidelines which emerged from the AR cycles.	None emerged. Although, to draw step 6 together, it should be emphasised that running the programme required constant "marketing" to sustain discretionary effort.

Figure 5.1: Steps and guidelines for the SD/DT process (page 7 of 10)

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SD/DT step 7 (from Figure 2.5)	Results from the AR cycles (see Section 4.3 for an explanation of how the AR cycles were initiated and run)
7.i. Use demonstrators and quick-wins to promote the concept of agility (sprints) and the minimum viable product.	**How:** This step in the SD/DT process ran up to workshop 7. The focal firm had established a Digital Academy for its own staff and, from workshop 2 onwards, its services were extended for use by the suppliers on the programme. This helped the group to begin to explore, together, some of the cultural aspects of 8.i. To many, concepts such as "failing fast" were very unfamiliar and, in the safety conscious aerospace sector, it was essential to set them into the right context. This particular concept was to prove highly relevant when the group's showcase quick-win project (called eDAR) failed to go-live as planned shortly after workshop 7. The reason was a shortfall against cyber-security requirements and, whilst some were left deflated, most focused on the positives and the learning which had been acquired. Nevertheless, overall, the experienced gained with the benefit of hindsight is to launch more projects, run them faster, and thereby deliver more quick-wins.
	Special Interventions: None taken.
	Adherence: This guideline was satisfied to a MEDIUM degree.
	Enablers: During workshop 4, a visit was made to what at the time was the Digital Manufacturing and Design Innovation Institute (DMDII). One of their funded research projects (14-06-01, MBE supply chain technical data package) had been recently completed. They gave permission for it to be used by the suppliers on the programme as the initial 'discovery' test case which all performed for benchmarking purposes.
	Blockers: Company funding was constrained and one of the most obvious projects to start could not be launched (i.e. the Global Supplier Portal).
	Criticality: This guideline is of HIGH criticality to the success of the SD/DT process.
7.ii. Recognise that at the start some may need more support than is the vision for the longer term and that it takes time to build trusting relationships. Therefore, be prepared to configure the approach to suit. Events on a 1:1 basis may help with engagement, diagnostics and prioritisation.	**How:** During this period, all suppliers on the programme were visited on a 1:1 basis at their home facility by the Network Champion (who was also the prime researcher). This established key contacts and provided a deeper appreciation of needs and expectations. It also helped to set the Network Champion as the common node and, over time, as a trusted confidant. Towards the end of this period, it was important to update and share progress with the broader supply base who had attended workshop 1 and been the original catalysts. This was done at workshop 6 in an unconventional, but inspiring, manner for which there was positive feedback. Suppliers on the programme shared their work under spotlights in an otherwise dark, smoke-filled, room. The mantra from the workshop 2 launch event was maintained of "working together to find our way through the digital fog".
	Special Interventions: Configuration of the approach to suit different contextual factors was developed further and used later in the programme. See Section 5.2.2.
	Adherence: This guideline was satisfied to a HIGH degree.
	Enablers: The global infrastructure of the focal firm. This made it relatively straight-forward for the Network Champion to visit the home facility of all suppliers with a translator, if required, together with local contacts who had a good grasp of the suppliers' business and priorities.
	Blockers: Diagnostics were initially attempted using the digital capability assessment tool (NIST, 2016). This was convenient, but proved relatively ineffective. With the benefit of hindsight, it may have delayed progress on what proved to be far more essential. Namely 8.i.
	Criticality: This guideline is of HIGH criticality to the success of the SD/DT process.
Any new guidelines which emerged from the AR cycles.	None emerged. Although, as was also raised in step 3 of the SD/DT process, the importance of creating a common vision and vocabulary at the earliest opportunity is further emphasised here. This is captured by guideline 8.i.

Figure 5.1: Steps and guidelines for the SD/DT process (page 8 of 10)

SD/DT step 8: Growth of results for the longer term

SD/DT step 8 (from Figure 2.5)	Results from the AR cycles (see Section 4.3 for an explanation of how the AR cycles were initiated and run)
8.i. Create a common vision and vocabulary.	**How:** This step in the SD/DT process ran up to approx. workshop 14; although steps 7 to 8 to 9 must be seen as being overlapping with their transition blurred and, if necessary, iterative. Key to step 8 is that those on the programme must have successfully developed and embedded a common vision and vocabulary. Two means of doing this were used. Firstly, the Digital Enterprise demonstrator to explore concepts, together, and to play out scenarios (see Section 1.3). Secondly, the creation of Digital Minimum Standards which are described in Section 5.2.3. Their initial construction emerged as an outcome of workshop 7. By workshop 14, they had moved from spreadsheet format, which was trialled by the suppliers on the programme, to storyboards for a digital APP which would be used later to diffuse into the broader supply base.
	Special Interventions: The digital APP which is described in Section 5.2.3.
	Adherence: This guideline was satisfied to a MEDIUM degree.
	Enablers: The Digital Enterprise demonstrator was initially created for other purposes, therefore, it was available for use by this programme on a free-of-charge basis (see Section 1.3).
	Blockers: Supplier feedback on the digital APP has been extremely positive. However, they have also indicated that it may have suffered from not following the approach of a minimum viable product. This may have allowed the key principles to have been cascaded and adopted sooner.
	Criticality: This guideline is of HIGH criticality to the success of the SD/DT process.
8.ii. Enhance long-term strategic road-mapping to include digital systems and data. Clearly articulate both the expectations and the value proposition.	**How:** The supplier scorecard is described in Section 3.3.2. A series of changes were made to each of the attributes (quality, cost, deliver, management, and technology) for 2019 which were communicated extensively, buyer-side and supplier-side, via multiple channels. Through this step in the SD/DT process, the criteria for the management and technology attributes were enhanced to include aspects relating to digital systems. However, attempts to reach out to the suppliers on the programme to link this into the cost attribute (i.e. the value proposition) did not get traction.
	Special Interventions: The ISS/SEP which is described in section 5.2.3.
	Adherence: This guideline was satisfied to a MEDIUM degree.
	Enablers: The construction of the scorecards was due an update, anyway, for 2019.
	Blockers: The value proposition for DT is complex and crosses a minefield of commercial issues.
	Criticality: This guideline is of HIGH criticality to the success of the SD/DT process.
8.iii. Each supplier must own their actions/roadmap. Install a feedback loop which includes monitoring of any 'knock-on' cumulative effects.	**How:** To maintain top-down senior programme sponsorship, buyer-side and supplier-side, it was essential for a feedback loop to be established through the executive system i.e. the supplier scorecard. This contributed to the changes in 8.ii. This was also used in the PhD research programme for triangulation purposes and the results are contained in Chapter 6.
	Special Interventions: The ISS/SEP which is described in section 5.2.3.
	Adherence: This guideline was satisfied to a LOW degree.
	Enablers: No negative 'knock-on' cumulative effects were found to have emerged.
	Blockers: Inherent communication problems across multiple parties within large firms.
	Criticality: This guideline is of HIGH criticality to the success of the SD/DT process.
8.iv. Keep it fresh - activities may be performed in phases.	**How:** By workshop 14, there were a total of eight projects in the programme which were at different phases in their life cycle. One project had been successfully completed (eFAIR). One project had been stopped just before go-live (eDAR – see 7.i). Two projects were approaching their deployment phase into the broader supply base (MBD; and Digital Minimum Standards – see 8.i). Four projects were in their initial discovery or capability development phases (DPEX; eFPA; MBE supplier portal; and the Digital Enterprise demonstrator).
	Special Interventions: Dynamic membership (de-selection & exit) is described in Section 5.2.4.
	Adherence: This guideline was satisfied to a HIGH degree.
	Enablers: None identified.
	Blockers: The generation of ideas for new projects was constrained at times by uncertainty over the scope of the programme. It was intended to be able to embrace new ways of working (i.e. digital/data rich), but tended to find most traction when focusing upon the transactional tools.
	Criticality: This guideline is of HIGH criticality to the success of the SD/DT process.
Any new guidelines which emerged from the AR cycles.	None emerged.

Figure 5.1: Steps and guidelines for the SD/DT process (page 9 of 10)

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SD/DT step 9 (from Figure 2.5)	Results from the AR cycles (see Section 4.3 for an explanation of how the AR cycles were initiated and run)
9.i. Integrate into the process for supplier performance management.	**How:** This final step in the SD/DT process started after approximately workshop 14; however, it has not been concluded to date. Key to step 9 is that the SD/DT process must have been successfully integrated and embedded. This is yet to be fully achieved and to do so requires both incorporation and systemisation into: Quality System (i.e. sourcing and supplier selection, ESCA, and supplier performance management, ISS/SEP); Production System (i.e. "How To" and "Best Practice" Guides), and the Commercial Negotiation Framework (e.g. Cost Levers). Nevertheless, progress to date is encouraging. An initial route-prover by the focal firm (Project Athena) has successfully used that described in 9.ii. for sourcing and supplier selection purposes.
	Special Interventions: The engagement and diffusion model which is described in Figure 5.2.
	Adherence: Progress to date is that this guideline has been satisfied to a HIGH degree.
	Enablers: Success here is built upon the previous steps of the SD/DT process.
	Blockers: At the time of writing, the world is grappling with the COVID-19 pandemic. It is currently uncertain how this will impact the continuation of the programme.
	Criticality: This guideline is of HIGH criticality to the success of the SD/DT process.
9.ii. Develop the concept of a minimum standard into a maturity model.	**How:** This covers the extension of 8.i. from that which is shared and used by only the suppliers on the programme to that which is diffused and adopted across the broader supply base. Also, the concept of the minimum standard needs to have moved up a level to one where it is recognised that the minimum standard increases over time and there are consequences if it is not achieved. Progress has been made on establishing such a maturity model, however, it has not been fully embedded to date. The digital APP is still being used for training and awareness purposes on both the buyer-side and the supplier-side. User registration provides an indication of diffusion. More work remains in 2020 to upskill the global workforce and to embed the key principles.
	Special Interventions: The digital APP which are described in Section 5.2.3.
	Adherence: Progress to date is that this guideline has been satisfied to a HIGH degree.
	Enablers: The production system used by the focal firm is constructed using a minimum standard framework; therefore, this was familiar to many on the buyer-side.
	Blockers: English is not the first language for some users of the digital APP. A mandarin version is being created, but it would have been even better if there had been a stronger focus (and funding) for a global communication strategy.
	Criticality: This guideline is of HIGH criticality to the success of the SD/DT process.
9.iii. Focus on inter-org or building the supplier's capability to self-improve.	**How:** Permutations to the operating model are described in 6.ii. By workshop 21, a network of complementary programmes had been established. Firstly, the original global programme which has been the main focus of this research. Others have included: regional (China), new product development (UltraFan®), and commodity sub-tier (Controls). Others in planning are: regional (India) and sector (Defence).
	Special Interventions: The engagement and diffusion model which is described in Figure 5.2. NPD, Commodity, and Regional programmes described in Section 5.2.2.
	Adherence: This guideline was satisfied to a HIGH degree.
	Enablers: Access to government and other research or support programmes.
	Blockers: Local resources and infrastructure needs to be secured or established if not already present.
	Criticality: This guideline is of HIGH criticality to the success of the SD/DT process.
Any new guidelines which emerged from the AR cycles.	None emerged. Although, it is worth reflecting here on the overall iterative nature of the SD/DT process. Returning back to 2.ii, for example, where even now top management support (both at focal firm and suppliers) remains key for sustainment.

Figure 5.1: Steps and guidelines for the SD/DT process (page 10 of 10)

5.2 Four categories of special intervention facilitate SD/DT process

Special interventions to facilitate the SD/DT process are grouped into four broad categories.

5.2.1 Special interventions taken to increase programme thickness

The concept of "*programme thickness*" is derived from that of "*institutional thickness*" in section 3.1.3c, namely: the presence of a plethora of different kinds of organisation, high levels of interaction amongst them, the development of patterns of coalition and collective action, and a sense of identity that they are involved in a common enterprise. Rather than the concept of thickness being applied to a physical locality, it is instead considered to apply here to the SD/DT programme.

Gaining programme thickness began with supplier selection at step 4 of the SD/DT process. A sense of that which was achieved is shown in Figure 4.5 and more detail is provided in Chapter 6 across all of the contextual factors. As was anticipated, the programme needed time to embed and mature in order to establish and develop the principles described above. However, over time, it was possible to gradually increase programme thickness through two special interventions of note.

Firstly, after supporting the launch of the programme at workshop 2, firms such as software vendors were re-introduced from workshop 14 onwards as shown in Figure 4.4 (c). The vision for this special intervention was as follows: the collective power of the enterprise was ready to be harnessed in order to help to resolve complex matters such as digital non-interoperability; and giving access to the software vendors to hear the voice of their customer base could serve to strengthen their support and grow the coalition. The status at workshop 21 was that requirements had become much better understood, by all parties, but there were no easy solutions identified. Nevertheless, actions were agreed and incorporated into one of the communities of practice which was launched for 2020.

Secondly, another special intervention which was taken to increase programme thickness was to provide firms with free access to specialist facilities and resources. This took the form of a prize for 2020. A sandpit environment, remote from their home production facilities, was offered together with supporting digital equipment and specialist staff. Firms applied for the prize with the only condition being that they had to be prepared to openly share their findings and outcomes. Selection was on the basis of the potential of their project to deliver multi-level benefits (firm, cohort, and network). At workshop 21, the winner presented their entry and the plan for 2020.

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5.2.2 Special interventions taken to organise the eclectic mix

Gardes et al (2015) identify differences between *"organic"* and *"synthetic"* groupings of firms and warn that the latter are at risk of being self-serving. I found that a balance was required between programme thickness and programme cohesion. These properties were emergent. At the launch workshop, the programme was envisaged as a single, stand-alone, global mix of suppliers operating to principles similar to those of a focus group and meeting only, say, a maximum of twice per year (see, for example, Krueger and Casey, 2015). In general, the appetite proved to be for more than this; however, different groups and interests were present. As such, the programme was not uniform and special interventions were required to organise the eclectic mix. The final composition which emerged is described below:

a) ***Regional***: The priority for this special intervention was given to China for a number of reasons (beyond my research objectives). The key issues which needed to be addressed were differences in digital maturity and preferred language of communication. Compared to most on the programme, the Chinese firms were at a lower level of digital maturity and were struggling to communicate effectively in English with the other firms. Workshops 11 and 17 were therefore designed to better satisfy their needs and to establish a regional cluster group. A hub-and-spoke operating model was adopted with the main (global) programme. It can be seen from Figure 4.4 that the firms in the study group who attended workshops 11 and 17 were Papa, Uniform, and Whiskey. Their triangulated outcomes at Waypoint A/B are provided in Chapter 6. It can be seen that two were unsuccessful and they remain at step 7 of the programme. Nevertheless, another (more positive) interpretation is that none have left the programme which, without this special intervention, would almost certainly have been the case.

b) ***New Product Development (NPD)***: An industrial prerequisite set for my research was to support the UltraFan® engine (section 1.5). I began by conducting exploratory interviews with staff from a few firms who had significant NPD experience. I focused upon the Joint Strike Fighter (JSF) Enterprise, because of its highly regarded collaborative digital environment (Sheridan and Burnes, 2018). From my exploratory interviews, I identified that a special intervention might help to bridge between project and commodity responsibilities within Rolls-Royce. The operational and strategic relationship with suppliers is commodity-owned, but the overall coordination and industrialisation during NPD is project-owned.

Thus, workshop 10 was designed exclusively for the smaller (fast-make) suppliers to the UltraFan® engine who had the weakest commodity-ownership. Also, workshop 13 was designed for a sample of other suppliers to the UltraFan® engine who had stronger commodity-ownership. It can be seen from Figure 4.4 that no firms from the study group attended workshop 10, but four attended workshops 13. These were Alpha, Bravo, Tango, and Zulu. Their triangulated outcomes at Waypoint A/B are provided in Chapter 6. It can be seen that one was unsuccessful and has left the programme, but three remain and have successfully progressed to step 8/9. The most significant achievement, however, culminated at workshop 18. At the commencement of my research, a significant risk on the UltraFan® engine was supply chain readiness for digital product definition (MBD). At workshop 18, a full state of readiness was confirmed with the firms present and a notice to suppliers (NTS478) was duly issued to the whole supply base in November 2019. No major issues with adoption have been reported since.

c) **Commodity**: Interview feedback was positive about the NPD special interventions made through workshops 10 and 13. One person reflected after a workshop that "*new business is coming and to win it there is a need for digital transformation*". Many appreciated the alignment of capability development with delivery onto a current live project. However, sourcing for the UltraFan® engine remains at a very preliminary stage; therefore, a further special intervention was taken with workshop 19. This brought together sub-tier suppliers from one specific commodity group. No firms from the main study group attended. Workshop 19 was found to be of mixed success. On the negative side, there has been a low level of follow-up in terms of the access requests from these particular firms to the APP for the digital minimum standards (section 5.2.3). On the positive side, one person commented after the workshop that "*my competitors and peers are on-board with digital transformation, so I must not get left behind*".

d) **Large Firm:** Two special interventions were taken with large firms. Inviting them to either host a group or a one-to-one workshop. These aimed to improve exposure to back-office digital specialists, leverage synergies, and help change agents to coordinate and disseminate. Six of the ten large firms in the study group had these special measures applied: Delta, Echo, Foxtrot, Golf, Kilo, and Papa. Chapter 6 shows that only one of the firms was unsuccessful at Waypoint A/B; however, multiple factors are at play. No conclusions can really be drawn from this. Anecdotally, deeper interfirm contacts were established and personal relationships have blossomed.

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5.2.3 Special interventions taken to diffuse across the broader supply base

The engagement and diffusion model evolved through a series of special interventions. The final version is shown in Figure 5.2. It was adapted and developed from Behrans (2008) who used it for lean manufacturing (section 2.2.10 point #3).

	Currently, is the supplier segmented by the focal firm as strategic?	Does the supplier possess capabilities for their own self-improvement?	The focus of the engagement approach taken by the focal firm	Examples of the key enablers
Engagement Level 1	YES	YES	Developing and improving enterprise-wide systems and processes, together	This increasingly became an important consideration for the selection of suppliers for the SD/DT programme (i.e. iterations of step 4). Diffusion beyond this was through the ISS/SEP and digital APP. Also, via workshops 6, 15, and 20.
Engagement Level 2	YES	NO	Identifying and closing the gaps to build capabilities, and/or make investment decisions, for the suppliers own self-improvement	In addition to the framework provided by the digital APP and ISS/SEP (see above), this is where the special interventions in sections 5.2.1 and 5.2.2 were most prevalent. Of particular note are: increasing programme thickness, facilitating regional clusters, and championing the change agents at large firms.
Engagement Level 3	NO	YES	Evaluating and selecting suppliers for future business and/or new opportunities	With an initial route-prover at the focal firm (Project Athena), the digital minimum standards were successfully used for sourcing and supplier selection purposes. Also, although not the prime focus of the workshops, potentially new or emergent suppliers were present at approx. a third of them (i.e. 4, 10, 11, 13, 17, 19 & 21).
Engagement Level 4	NO	NO	Promoting a network of third parties to help suppliers to reach their own self-improvement plateau	Increasing programme thickness (see section 5.2.1) was used here and, in particular, as a concept for building the regional cluster in China (see section 5.2.2). A mandarin version of the digital APP is being created to provide a consistent framework.

Figure 5.2: Engagement and diffusion model used for the SD/DT process
(adapted and developed from Behrans, 2008)

The engagement and diffusion model helped to direct the effort and resources of the focal firm. For example, in relation to engagement level 4 in Figure 5.2 and the regional special intervention in section 5.2.2. The latter is intended to deliver the former. Otherwise, there is no exit strategy as was found by Boeing after two decades with some of their Chinese aerospace suppliers (Liu, 2009).

Figures 5.1 and 5.2 mention the supplier scorecard, or it's abbreviation of ISS/SEP (section 3.3.2), digital minimum standards, and the APP for training and awareness. In Figure 5.1, against guideline 8.ii, it explains that an update to all attributes in the ISS/SEP was performed for 2019. My research primarily influenced three aspects of this.

Firstly, the number of suppliers for whom technology was an attribute in their ISS/SEP was reduced in order to focus effort on both sides. This took effect from the start of 2019 onwards. The impact upon my study group of 24 suppliers can be seen through Appendix A and, in summary, was that: 14 (58%) continued to have technology as an attribute in their ISS/SEP; 6 (25%) ceased to have it but continue to be classed as 'sustaining' suppliers; 1 (4%) was added and is classed as an 'emerging' supplier; and 3 (13%) have never had it and remain classed as 'special case'. Overall, my study group now represents about a third of the supply base for whom technology is an attribute in their ISS/SEP.

Secondly, the question-set for the technology attribute in the ISS/SEP was updated. The scope was previously product and manufacturing process technology. It was expanded to include digital systems capability. The net effect was a 20% change in how suppliers were scored; however, this was introduced very gradually during 2019. A framework of digital minimum standards was used. This was co-created by the firms on the SD/DT programme to establish a common vision and vocabulary for a Digital Enterprise. A neutral, functionality-based, framework is provided which is agnostic to the branding and specificity of software or tools. An indication of diffusion is provided by Figure 5.3.

Thirdly, an APP was created to provide training on the above. Figure 5.4 gives sample screenshots.
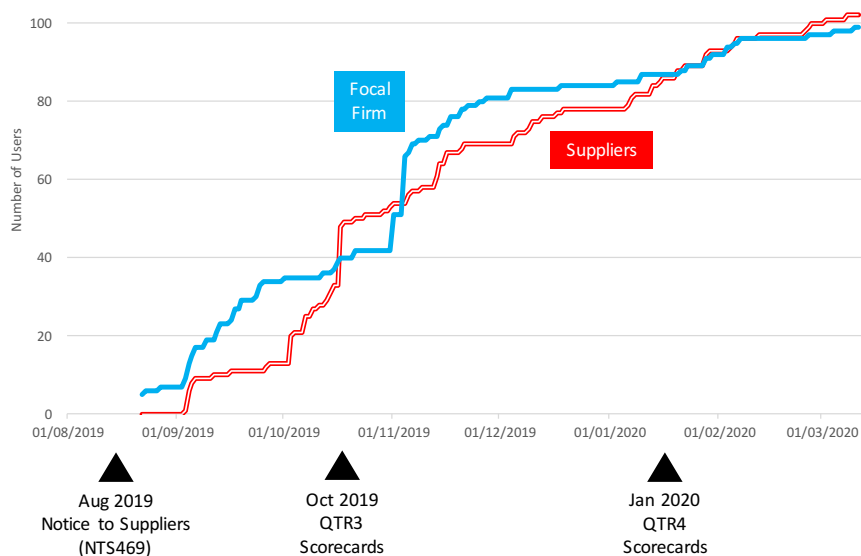
Figure 5.3: Requests for access to the APP for the digital minimum standards

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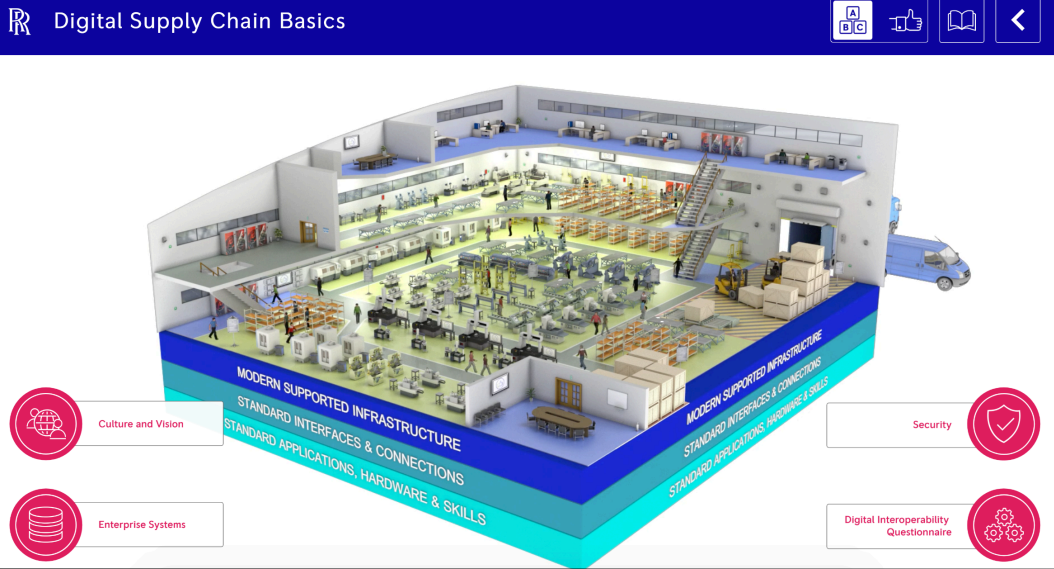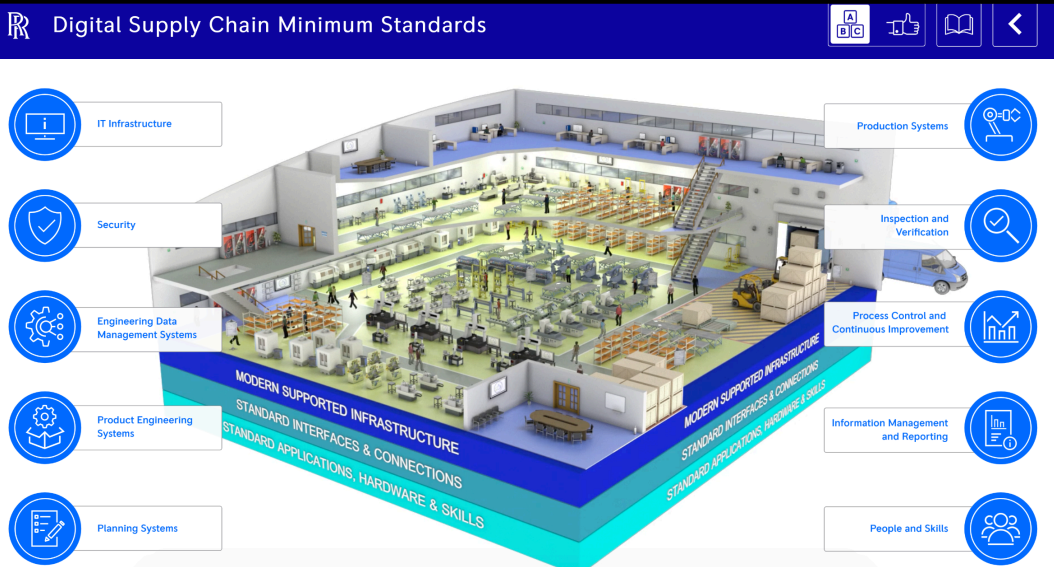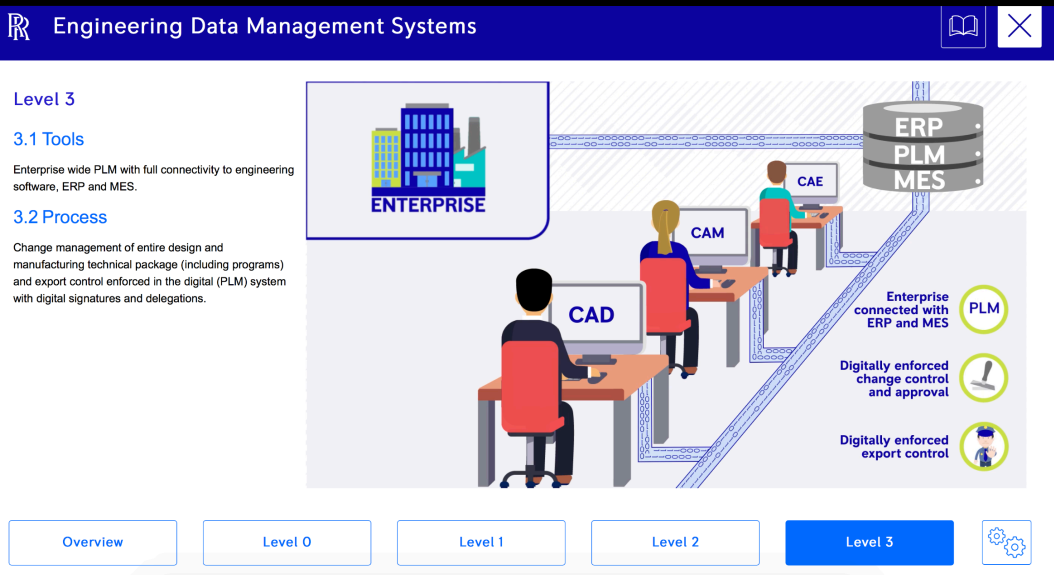
Figure 5.4: Screenshots from the APP for the digital minimum standards

5.2.4 Special interventions taken to establish a dynamic model of membership

A few matters instigated this special intervention. Firstly, as described in Figure 5.1 (step 4), the programme was over-subscribed at launch and, throughout the period of my research, demand exceeded capacity. Secondly, by also removing the ISS/SEP technology attribute from some suppliers for 2019 onwards, there was a risk that they may perceive that digital transformation was not seen as relevant to them and/or they may become disenfranchised about future business.

Therefore, workshops 6, 15, and 20 were designed to respond to these matters, because the whole supply base were in attendance (i.e. approx. 100 suppliers who were assessed as being the most strategically important or operationally significant to Rolls-Royce). Interactive, peer-to-peer, presentations were delivered together with informal question and answer sessions. The workshops are included in Figure 5.2 and this overarching framework helped to target the approach and construct the key messages. All suppliers were given a few requirements for 2019 onwards as 'digital basics' in the management attribute of the ISS/SEP. These are summarised at the top of Figure 5.4. They were not onerous, but promoted dialogue and the use of the APP.

Supplier membership of the SD/DT programme was typically reviewed annually with their Rolls-Royce buyers. Changes in the membership status of my study group occurred in 2018 (at workshops 9, 11, and 12), 2019 (at workshop 18), and 2020 (at workshop 21). For those firms who were members of the programme for 2020, the style of participation evolved to that of four communities of practice: commodity twin, production twin, eProcurement, and digital minimum standards. Memberships and roles were agreed at the end of 2019, each community of practice held at least one launch meeting by WebEx at the beginning of 2020, and then they presented their project charters and plans at workshop 21. The operating model which they devised is shown in Figure 5.5.

Purpose of CoP	Role of members

• Provide a forum for identified members to:
     o Share knowledge and best practice.
     o Seek help and guidance.
     o Look at new & emerging technology/capability.
	• Possess & develop detailed knowledge of subject.
	 • Act as the point of contact for their business users.
	 • Be an effective communicator and change agent.

Desired outcomes	**Typical tasks within role**
• Network of like-minded individuals. • More informed community. • Sharing of best practices and lessons learnt. • Capability & skills requirements better understood. • Work as one to leverage standards and solutions.	• Cascade and communication in own business. • Sharing and escalation of common issues. • Support capability development & implementation (People/Process/Tools).

Figure 5.5: Operating model for 2020 communities of practice

5.3 Summary of key implications from this chapter

This section begins by comparing my results with the research from others. Then, I summarise the business and academic contribution. Finally, I identify items for discussion in chapter 7.

5.3.1 Comparing my results with the research from others

All of the evidence gathered points to mine being the first derivation of the SD/DT, or equivalent, process. This has been the consistent message from the firms in my study group and the others who were co-opted onto the programme. Many are able to provide a broad perspective from having worked closely with other focal firms in the aerospace industry and beyond.

In Figure 5.6, I return to the work of Bokinge and Malmqvist (2012) on PLM implementation for a comparison of results. We identify a similar number of guidelines and our assessments of their criticality are similarly distributed. However, there is a significant difference in adherence to the guidelines. This is not entirely unexpected, because our research methodologies are very different. Bokinge and Malmqvist first generate their guidelines and then perform a retrospective case study to see if they are being followed in practice. I generate an initial version in a similar manner, but then go through 44+ iterative cycles of plan–act/observe–reflect as described in Figure 4.2. Nevertheless, Bokinge and Malmqvist argue that adherence to guidelines remains a common problem even if they are readily available. My speculation is that the structure and scrutiny of my action research programme may have mitigated this. Furthermore, the extension of my guidelines through special interventions may have made them more transferable. Overall, in addition to the four persons who counter-checked and amended my guidelines during their generation, I am satisfied from this comparison of results that mine have been categorised appropriately at an elemental level.

Criticality or relevance of the guideline	SD/DT (Figure 5.1)	PLM (Bokinge and Malmqvist, 2012)
HIGH	22 (79%)	20 (84%)
MEDIUM	6 (21%)	2 (8%)
LOW	0	2 (8%)
Adherence to the guideline		
HIGH	16 (57%)	1 (4%)
MEDIUM	9 (32%)	6 (25%)
LOW	3 (11%)	17 (71%)

Figure 5.6: Comparison of guidelines (SD/DT and PLM)

5.3.2 Business contribution

This section was prepared with one of my industrial supervisors (Ian Molyneux, Procurement Executive). There has undoubtedly been a positive business contribution from my research. The Extended Enterprise has been inspired about the Digital Enterprise, the consistent development of the vision since 2017, and the highly collaborative approach used to move towards it. At the time of writing in March 2020, there are 10 suppliers who have fully achieved the digital minimum standards and 39 (including the 10) with a gap closure or continuous improvement plan for 2020. Also, over 200 members of staff, dispersed globally across the Extended Enterprise (focal firm and its supply base), have accessed the training APP.

Furthermore, the comprehensive documentation which has been generated for the SD/DT process (Figure 5.1) has allowed it to be widely shared with others. As a result, two representatives from another Rolls-Royce business sector attended workshop 21 as observers with a view to launch their own programme later in 2020. Also, subject to the outcome of the COVID-19 pandemic, there are plans to launch another regional cluster group in India in 2020Q3 similar to that launched in China.

Another significant business contribution from my research was the achievement of supply chain readiness for digital product definition (MBD) on the UltraFan® and other engines in November 2019 (NTS478). The firms on the SD/DT programme performed trials, test cases, user acceptance testing, and lessons learnt reviews. The total gearing of investment for the focal firm is estimated at 5:1.

Thus, many positives. However, to put these into perspective it would be fair to say that the programme was of its time. Aoki and Lennerfors (2013) describe a period of cut-costing which preceded the launch of the programme. Many firms then swung the other way. My research, for example, contributed to Rolls-Royce receiving the top award from the Chartered Institute of Procurement and Supply (CIPS) in 2019 for their submission on creating collaborative supply chains (CIPS, 2019). Nevertheless, looking forward, it is fitting to reflect upon the term "*value-driven*" in Figure 1.4. Firms must have strong relationships but, in order to survive, they require them together with strong operational performance. Relatively speaking from a business perspective, the SD/DT programme has undergone a long gestation. A platform has now been established, but it remains uncertain exactly how business value will continue to be extracted and to grow. Important questions remain, for example, if/how joint investment should be tackled at enterprise-level and firm-level.

5.3.3 Academic contribution

The academic contributions which I have made in Chapter 5 can be summarised as:

a) Advanced the SD/DT process through action research to culminate in the definition of nine steps, twenty-eight guidelines, and four categories of special intervention.

b) Added to literature on work-based research. Section 7.3 discusses this further.

c) Exposed evidence to suggest that the SD/DT process may answer my research question (i.e. how to develop suppliers within an extended enterprise towards a digital enterprise). Chapter 6 moves onto review the outcomes for the cohort of 24 suppliers.

5.3.4 Items for discussion in Chapter 7

Chapter 7 reviews the combined results from this and the next chapter. The discussion seeks to explore common, or unifying, themes and unresolved significant issues. Hence, this section points out the topics which are carried forward.

Chapter 5 has shown the digital minimum standards to emerge as the instrument for sharing best practice within this specific case of an Extended (Digital) Enterprise. The emergence of best practice sharing is in accordance with Chandler and Hwang (2015) and my theoretical framework shown in Figures 3.2 and 3.9. Furthermore, Figure 5.3 has provided some indication of diffusion; albeit, still very early days. Therefore, Chapter 7 discusses whether potential adopters will continue to have good reason to perceive the digital minimum standards positively. Also, it discusses the next phase in their deployment. Should the standard remain unchanged for the time-being or should the bar start to be raised?

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Chapter 6

RESULTS (part 2 of 2)

Outcomes from the SD/DT process
for the cohort of 24 suppliers

Chapters 1 and 2 set the scene and synthesised process-steps for organisational change from literature. Chapters 3 and 4 constructed a theoretical framework and introduced my research methodology. Chapter 5 provided the first part of my empirical results in the form of a comprehensive description of the SD/DT process.

Now, chapter 6 provides the second part of my empirical results in the form of the outcomes from the SD/DT process for the cohort of 24 suppliers. This chapter is divided into three sections from 6.1 to 6.3. It begins by comparing and triangulating my results. This identifies two groups of particular interest: 6 firms who have unsuccessful outcomes to date, and 3 firms where my results do not triangulate. The former is reviewed in section 6.1 and the latter in section 6.2. Finally, section 6.3 summarises and draws out the key implications. The empirical results show that my organisational change process answers the research question. It has a high success rate together with high potential to be operationalised and embedded through the supplier scorecards. A bullet-point executive summary is given overleaf for those who prefer this format.

Section 6.1   **Triangulating relative absorptive capacity to supplier outcomes at Waypoint A/B**

- 15 firms have successful outcomes at Waypoint A/B. They are also forecast to do so by their supplier scorecards and, therein, by my proxy for their relative absorptive capacity. Therefore, in their case, my results triangulate.

- 3 other firms (Foxtrot, Indigo, and Juliet) also have successful outcomes at Waypoint A/B. However, in their case, this is not forecast by their supplier scorecards. Therefore, their results do not triangulate. These firms remain on the SD/DT programme and they are reviewed in more detail in section 6.2.

- 6 firms (Charlie, Oskar, Papa, Romeo, Tango, and Whiskey) have unsuccessful outcomes at Waypoint A/B. Nevertheless, this is forecast by their supplier scorecards and, therein, by my proxy for their relative absorptive capacity. Therefore, their results also triangulate. A range of contextual factors contribute to their unsuccessful outcomes. Each has its own nuances. But, the overall net effect as it relates to the SD/DT programme has been captured consistently through their supplier scorecards.

Section 6.2   **Three cases where my results do not triangulate**

- Foxtrot are characterised as a taker (i.e. cautious and self-protective). My results for them may not have triangulated, because of: different levels of granularity in the assessments coupled with the complex, dynamic, and subjective nature of buyer/supplier relationships.

- Indigo are characterised as a giver (i.e. networker, collaborator, and influencer). They are also an important growth supplier, however, with this comes promises and expectations. My results for them may not have triangulated, because of: (a) an impatience for results in their supplier scorecard assessment, versus (b) more allowance for the voluntary nature of the SD/DT programme in my interviews.

- Juliet are characterised as a laggard (i.e. late adopter and suspicious of change agents). My results for them may not have triangulated, because of: (a) staff going through the motions and blindly tracking deliverables in the supplier scorecard assessment, versus (b) deeper probing in my interviews to grasp the full context.

- Overall, in conclusion, we should not be surprised that my results did not triangulate at precise spot-points in time for every firm. The supplier scorecards are subject to measurement bias. This is discussed further in chapter 7.

Section 6.3   **Summary of key implications from this chapter**

- Provided evidence that the SD/DT process can answer the research question.

- Supported the fusion of institutional and organisational learning theories with empirical research.

- Advanced the operationalisation and measurement of relative absorptive capacity using a novel approach, supplier scorecards.

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6.1 Triangulating absorptive capacity to outcomes at Waypoint A/B

Appendix A shows the trend in supplier scorecard results, over nearly four years, for the twenty-four suppliers in my main study group. This data is used as a proxy to measure their relative absorptive capacity as explained in section 3.3.2. Using Figure 3.6, the suppliers' 2019Q4 status is recorded together with a supplementary symbol if the following apply: "+" if the trend in their technology score has been generally increasing since the supplier joined the SD/DT programme; "–" if the trend in their technology score has been generally reducing since the supplier joined the SD/DT programme; and "#" if they have no supplier scorecard (technology) in 2019Q4 and therefore their result is based upon historical evidence and/or an interview with their buyer at Rolls-Royce.

Figure 6.1 compares the relative absorptive capacity at 2019Q4 (Appendix A) with the outcome at Waypoint A/B. The latter is assessed using success criteria which is mainly qualitative (Figure 4.7).

	Relative absorptive capacity points **incorrectly** to the outcome for the supplier	Relative absorptive capacity points **correctly** to the outcome for the supplier
Successful outcome from the SD/DT process (Waypoint A/B in accordance with section 4.4.2)	**AC3 –** Indigo Juliet **AC4** Foxtrot	**AC1** Bravo Echo Golf Hotel Kilo Lima **AC1#** Quebec Sierra Uniform Victor X-ray Yankee Zulu **AC2** Alpha Delta
Unsuccessful outcome from the SD/DT process (Waypoint A/B in accordance with section 4.4.2)		**AC2 –** Oskar **AC3#** Whiskey **AC3 –** Charlie **AC4** Papa **AC4#** Romeo Tango

Figure 6.1: Triangulating relative absorptive capacity to outcomes at Waypoint A/B

My analysis will primarily focus upon two groups from Figure 6.1. Firstly, the group of six suppliers (Charlie, Oskar, Papa, Romeo, Tango, and Whiskey) who were judged to have unsuccessful outcomes from the SD/DT process. Secondly, the group of three suppliers (Foxtrot, Indigo, and Juliet) where my results have not triangulated. These suppliers had successful outcomes, but contrary to what was forecast by the measurement of their relative absorptive capacity using the supplier scorecards.

A summary of the results and contextual factors for the first group of suppliers is provided below in Figure 6.2. Individual uncollated results for each of the three suppliers in the second group (i.e. Foxtrot, Indigo, and Juliet) are given later in section 6.2.

Supplier Name	Reason for unsuccessful outcome (section 4.4.2)		Contextual factors (section 3.3)		Current status in the SD/DT programme (March 2020)
	Waypoint A	Waypoint B	Relative absorptive capacity	Others which most greatly contributed to unsuccessful outcome	
Charlie	Avoidance	Their buyer-side interview most greatly contributed to their classification of having had an unsuccessful outcome to date	AC3 −	Firm Size (Large)	Step 8/9
Oskar	Manipulation	Their buyer-side interview most greatly contributed to their classification of having had an unsuccessful outcome to date	AC2 −	Strategic Alignment (sub-optimal) + Power Regime (supplier dominance)	Step 8/9
Papa	They have not passed through Waypoint A because they have been moved into a regional cluster group instead		AC4	Firm Location (Asia)	Step 7
Romeo	They were exited from the SD/DT programme at, or before, Waypoint A based upon their buyer-side interview		AC4 #	Strategic Alignment (sub-optimal) + Power Regime (supplier dominance)	Exited
Tango	They were exited from the SD/DT programme at, or before, Waypoint A based upon their buyer-side interview		AC4 #	Firm Size (Small)	Exited
Whiskey	They have not passed through Waypoint A because they have been moved into a regional cluster group instead		AC3 #	Firm Location (Asia)	Step 7

Figure 6.2: Summary for suppliers with unsuccessful outcomes at Waypoint A/B

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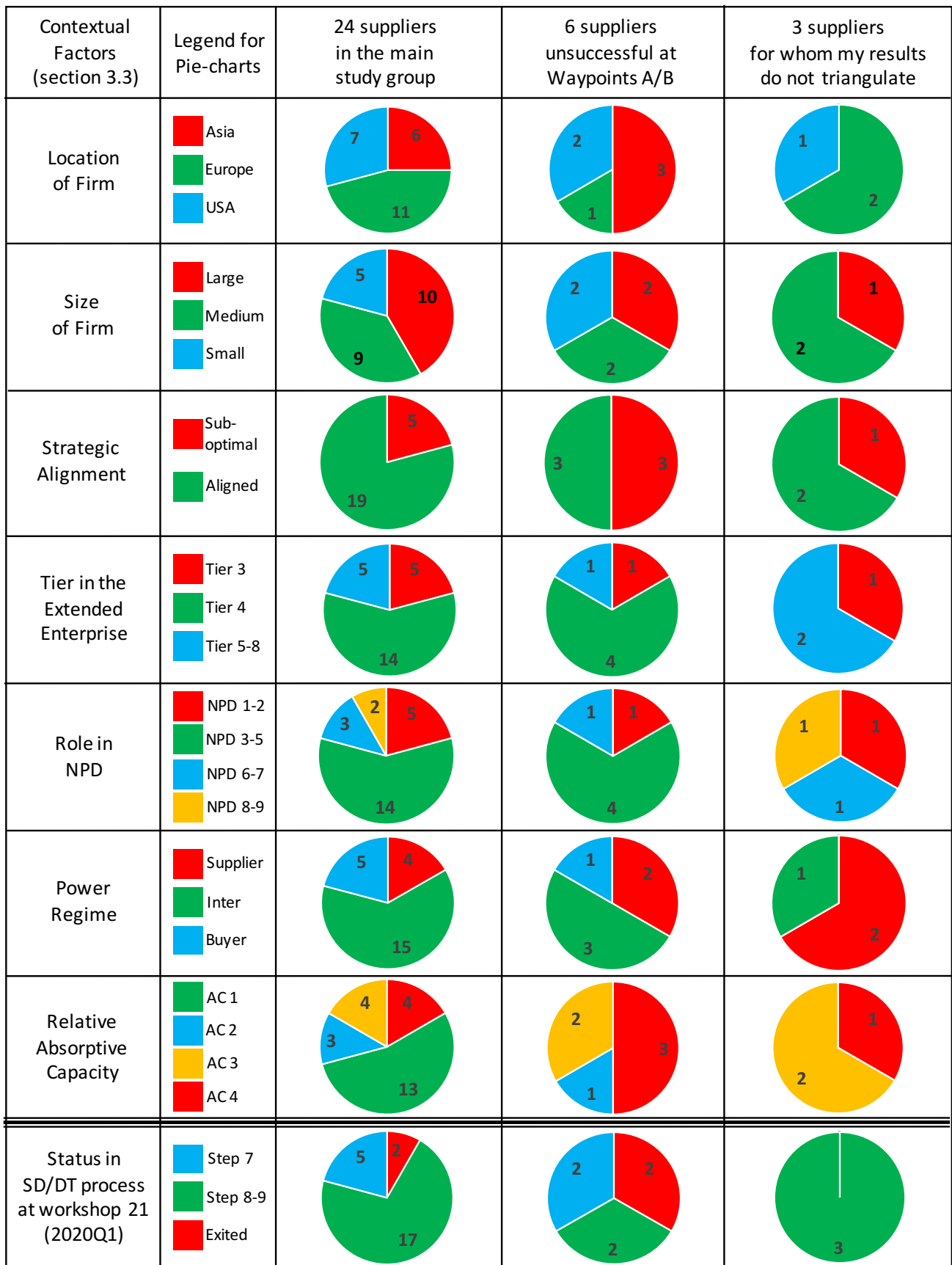
Figure 6.3: Contextual factors for the different groups of suppliers

Figures 6.3 and 6.4 provide further summaries for the two groups of suppliers in relation to the rest of the cohort on the SD/DT programme.

Waypoint A (section 3.4)	Waypoint B (section 3.5)		Current status in the SD/DT programme (March 2020)			Those firms for whom my results do not triangulate
	Successful Outcome	Unsuccessful Outcome	Step 7	Step 8/9	Exited	
Acquiescence	14	0	3	11	0	1 (Indigo)
Compromise	3	0	0	3	0	2 (Foxtrot) (Juliet)
Avoidance	1	1 (Charlie)	0	2	0	0
Manipulation	0	1 (Oskar)	0	1	0	0
Defiance	0	0	0	0	0	0
Those firms who have not passed through Waypoint A (as of March 2020)	0	4 (unsuccessful at, or up to, Waypoint A)	2 (Papa) (Whiskey)	0	2 (Romeo) (Tango)	0

Figure 6.4: Distribution of results throughout the SD/DT programme

The remainder of this section reviews and analyses the results for the group of six suppliers (Charlie, Oskar, Papa, Romeo, Tango, and Whiskey) who were judged to have unsuccessful outcomes from the SD/DT process. Section 6.2 then moves onto consider the other group of three suppliers (Foxtrot, Indigo, and Juliet) for whom my results do not triangulate. A relatively broad and high-level approach is taken to the former versus a more detailed approach to the latter. A balance is required between academic rigour and commercial sensitivity which I am able to achieve by reporting this way. Even if my thesis word-count had allowed, I need to avoid getting into too much detail on many of the twenty-four suppliers because it is through the detail that their identity emerges. However, each has a fascinating story to tell. I have been very privileged to study them all and to be able to extract the illustrative and informative examples which I have.

Starting first with Oskar. It can be seen from Figure 6.1 that they are an outlier. Their relative absorptive capacity at 2019Q4 had a generally satisfactory return from their supplier scorecard (technology) i.e. they were not AC3 or AC4 in Figure 3.6. They fell over the line in my classification, because of a sustained negative trend which had reached the point at 2019Q4 whereby they were very close to AC4. However, as they were a marginal case, I reviewed the triangulation of their results

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in Figure 6.1 with their buyer from different perspectives. An upbeat view for triangulation (i.e. successful outcome/AC2 or unsuccessful outcome/AC2–) versus a downbeat view for triangulation (i.e. successful outcome/ AC2– or unsuccessful outcome/AC2). The position shown in Figure 6.1 is that which was agreed. All is not lost with them and they remain members of the SD/DT programme.

Charlie is the only other supplier with unsuccessful outcomes who has remained a member of the SD/DT programme and progressed through to step 8/9. Similar to Oskar, they are reporting continued business value from membership and their buyer also wishes for them to remain in the hope that more is yet to come. There is some reason to believe that this could occur. In addition to Oskar and Charlie, there is a third supplier who had one of the more confrontational response strategies at Waypoint A (i.e. avoidance), but is shown in Figure 6.4 as having been successful at Waypoint B. For reference, Victor is the name of this supplier who successfully turned it around.

Another two of the suppliers with unsuccessful outcomes, Papa and Whiskey, have instead been moved to a regional cluster group (section 5.2.2). This was in response to issues with communication, ease of access, and digital immaturity relative to the others in the cohort. As such, whilst the cluster is bedding-in, they remain at step 7 of the SD/DT programme. By contrast, Romeo and Tango have exited the programme altogether. In addition to relative absorptive capacity, Romeo was influenced by strategic alignment (sub-optimal) and power regime (supplier dominance) which effectively drove the dyadic relationship apart. Tango was influenced by firm size (small) which eventually led to a re-prioritisation of their finite resources.

Thus, a range of contextual factors have been shown to contribute to the unsuccessful outcomes of all six suppliers. Each has its own nuances. But, the overall net effect as it relates to the SD/DT programme has been captured consistently through the supplier scorecards, and, therein, by my proxy for their relative absorptive capacity.

Finally, it is appropriate to return to Figure 6.1 and the fact that there are no improving trends (i.e. no supplementary "+" symbols). There are examples of performance levels being sustained (or reduced), but none showing significant improvement. Nevertheless, the word collage in Figure 6.5 provides some solace. It shows an illustrative quote for half of the words selected from Figure 4.6 in response to the question "What is your firms purpose in being on the SD/DT programme?". Furthermore, quotes for the remaining nine words which were selected are provided in section 6.2.

Benchmarking	Discovering	Explaining
"We're benchmarking a little bit. Looking at what others are doing and where we stand compared to our, well, the companies we work with but also our competitors. Are we developing [the best] solutions right now? … [otherwise] we're all be shaped by our pre-knowledge."	*"If you go back to when things kicked-off, and where [company name] was at that time, we were discovering and understanding what it was Rolls-Royce was looking to do … and of course from there until now our understanding has evolved … and this led to some really structural changes [in our firm] with [employee name] charting our digital strategy moving forward."*	*"People [others on the SD/DT programme] are full of serious information about a complete digital system … we are less mature, but from now we're fully engaged … we need to move quickly to catch up … I report to my seniors, they support me, we want to work out overall framework, plan, and then promote step-by-step … in our company we are explaining and sharing digital experiences."*
Delta	**Bravo**	**Uniform**
Translating	**Complying**	**Reciprocating**
"The problem that I see with [large OEM's] is that a lot of translation needs to happen to break their big corporate schemes down to our little scale … I think the [SD/DT programme] has done its share for that."	*"Here I'm a little bit conflicted, but I'd probably say … compliant. As a good supplier, needing to comply with where the customers are going. Probably more compliance than acquiescence if you see what I mean. Also, [from the row of related words] aligning ourselves with the customers and where they're going. Probably more so than integrating and sponsoring."*	*"I think there's some stuff that we are already doing, without getting into levels of intellectual property and all that, that would be straightforward for us to share. Good practice which other people could benefit from. And I think there's stuff that other businesses probably do better than us and we can get some benefit from. So it is about sharing. It can't be just take, take, take."*
X-Ray	**Oskar**	**Sierra**
Influencing	**Waiting**	**Testing**
"We are trying to influence and innovate with our software vendors because we want to have more [digital] functionality … we're learning about the functionality and we try to understand the philosophies … we try to develop our processes and the processes in the software as well … we try to influence and manipulate the future or the next steps from these software vendors."	*"Initially it was wait and see what happens … we were not knowledgeable and we had not dealt a lot with digital transformation before. It was hard for us to transition from let's wait and see to what do we need to do next … there was a scepticism in [company name] simply because many people involved did not deal with the topic of digital transformation hands-on … we needed to get aligned internally. Here, the [SD/DT programme] was really very, very helpful."*	*"I read it [testing] first and I said, boy, is that too negative. But then I thought that there are certain things … that are clearly not being thought through from a supplier perspective [example] I brought it up afterwards with him and he said like yes, that's a good thought, let me take that back … It's like saying, wait a minute now, you guys are designing this world from a Rolls-Royce perspective but did you consider this, this, this? And that's where I think is a big part of our role [in the SD/DT programme] is to say, hey wait a minute, did anybody consider this before you make this decision?"*
Echo	**Kilo**	**Quebec**

Figure 6.5: What is your firms purpose in being on the SD/DT programme?
(sample of responses from Waypoint B)

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6.2   Three cases where my results do not triangulate

The twenty suppliers who progressed to Waypoint B had three word choices each from Figure 4.6. They selected eighteen different words in total. The groupings are retained below in Figure 6.6. Shown explicitly are the responses from the three suppliers where my results do not triangulate.
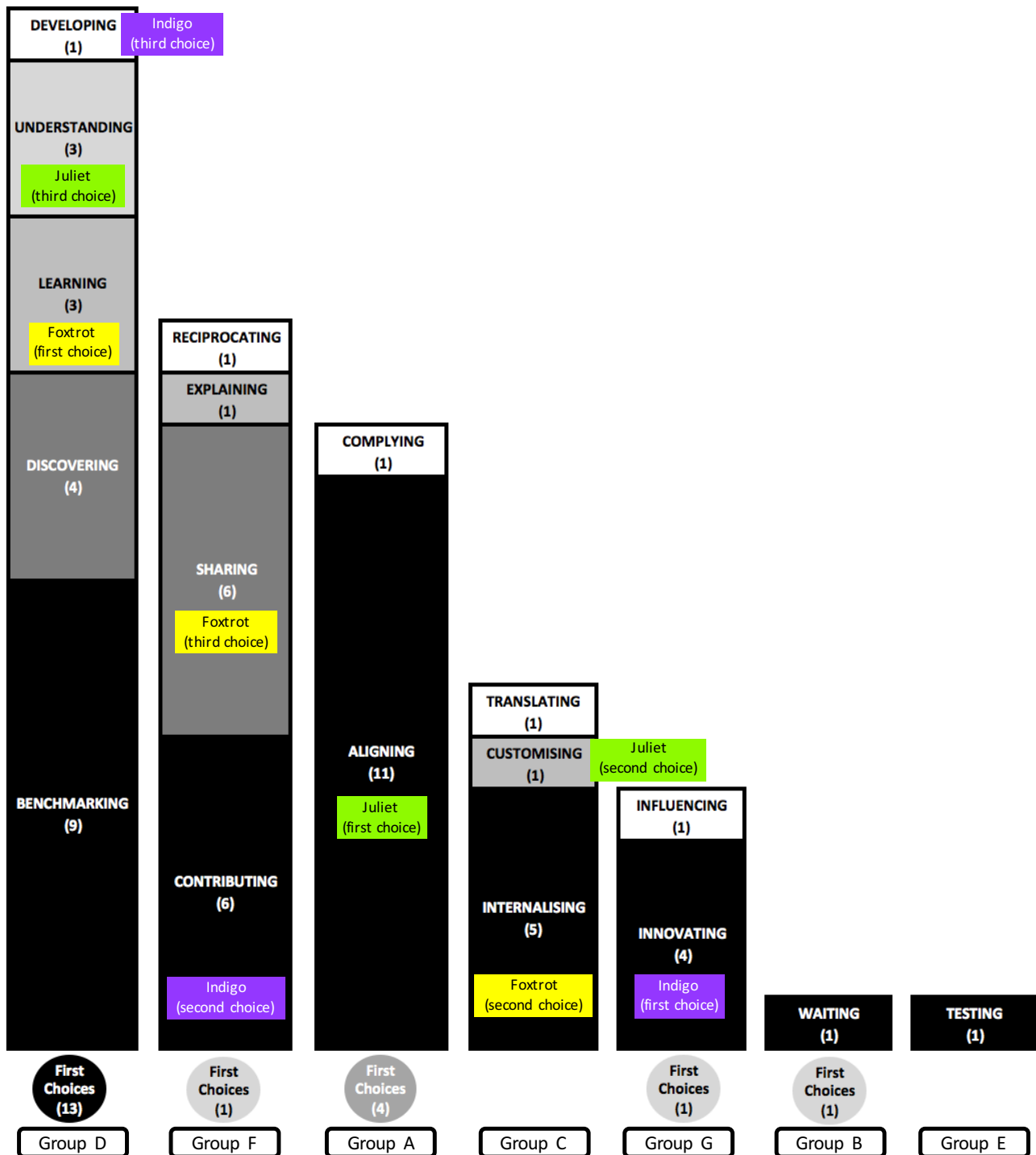
Figure 6.6: What is your firms purpose in being on the SD/DT programme?
(all responses from Waypoint B)

Starting with a few general observations about Figure 6.6. Firstly, no suppliers selected any words originating from Figure 3.8 (i.e. acquiescing, avoiding, compromising, defying, nor manipulating). The quote from Oskar in Figure 6.5, for example, shows their deliberation and choice of "*complying*" over "*acquiescing*". The negative connotation of the words in Figure 3.8 was identified during the buyer-side interviews and my response framework was redesigned accordingly for the supplier-side interviews (section 4.4.1). There is a risk that I may have overdone it. For example, Dayal (2016), who studies the syntax and semantics of questions, points to this problem; albeit in the case of highly polar questions whereas mine are more graded and listed.

However, Robinson and Leonard (2019) provide an alternative view which I consider to be a fair reflection having conducted the interviews. They argue that there is a place for framing questions such as mine in order to increase the likelihood of respondents responding on sensitive matters. The quote from Quebec in Figure 6.5, for example, shows their deliberation and careful selection of "*testing*". Overall, I found the supplier responses to be very rich and informative. The respondents openly provided a detailed explanation of their firm's behaviour (commercially driven or otherwise) through their explanation of a specific word selection and their discussion about the other words which they had included or rejected alongside it.

Figure 6.6 shows that the most popular groups of words selected from Figure 4.6 are the new ones which did not originate from Figure 3.8 (i.e. Group D which contains "*learning*" and Group F which contains "*sharing*"). These point to aspects of my theoretical framework in section 3.5 and support the view that adoption and diffusion is taking place. Furthermore, the third most popular group of words is Group A which is the one which contains "*acquiescing*" (Note: although nobody selected this word from the group, it is the one which is used to describe the desired response from the theoretical framework in section 3.4). Also, within Group A lies the most popular singular word selected by the suppliers which was "*aligning*" (Note: the word which the buyers used to summarise that which was of most importance to them in section 4.4.2). Overall, an encouraging set of results from Figure 6.6.

Moving next to the three suppliers where my results did not triangulate. The complexity and confidentiality of the subject, and the nature of my enquiry and research positionality, are such that I cannot be absolutely categorical on the root cause. However, I've written each as a case to highlight important aspects of consideration in the maze of potential contributory factors.

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6.2.1 The case of the taker (Foxtrot)

Here, I review the case of Foxtrot in order to explore aspects which are special, or unique, about them which may have led to a lack of triangulation in my results. Foxtrot were judged to have a successful outcome at Waypoint B, but their relative absorptive capacity at 2019Q4 of AC4 (as measured through the supplier scorecards) did not triangulate with this. Appendix A shows that the relationship has struggled over many years. Furthermore, their organisational proximity is sub-optimal and the power regime is supplier dominance throughout the research period. These contextual factors suggest a higher probability for Foxtrot, than many others in the cohort, to be unsuccessful on the SD/DT programme. However, they were not. Why might this be the case?

An important aspect of consideration which may have contributed to the lack of triangulation is that they were the most extreme case of a "*taker*" from the cohort of twenty-four suppliers on the SD/DT programme. Grant (2013) includes in his attributes and characteristics of a taker that they are "*cautious and self-protective*" whereas, in contrast, a giver will "*contribute without keeping score*".

Figure 6.7 shows quotes from, and about, Foxtrot which were taken on three occasions during the SD/DT programme. Firstly, an exercise was performed on the role of all attendees as change agents at one of the workshops held shortly before their Waypoint A buyer-side interview. Feedback forms were collected and extracts from Foxtrot's response are shown in Figure 6.7. Also included are the words selected, and quotations given, during their Waypoint A buyer-side interview and their Waypoint B supplier-side interview. A high level of frustration is clear from the buyer-side interview. There is reason to support their view, that Foxtrot are very inward-facing, from both the change agent form and the supplier-side interview. However, evidence can also be seen that Foxtrot are starting to embrace the digital minimum standards and show signs of becoming more willing to share.

This demonstrates the complex, dynamic, and subjective nature of buyer/supplier relationships. The predominately qualitative success criteria for Waypoint A/B (section 4.4.2) is more tolerant of this than my attempt to operationalise and measure relative absorptive capacity quantitatively via supplier scorecards. I should, therefore, not be surprised that some cases do not triangulate perfectly at a specific point in time. At one stage, Foxtrot's buyer was resigned to asking them to leave the SD/DT programme. However, rather than doing this outright, the decision was taken to test their commitment and resolve through the Waypoint B supplier-side interview. This turned out to be much more positive and stronger than the buyer had expected and so they have remained.

Another contributory factor to the lack of triangulation in my results for Foxtrot may come from subtle differences in the management of expectations. The grounding for the supplier scorecards, from which my measurement of relative absorptive capacity is taken, is in product technology (i.e. where the expectation of the buyer is that the supplier will make the dominant contribution) as opposed to digital technology (i.e. where it is more fluid and the scope extends to learning together).

Foxtrot were criticised about their approach to product technology in their buyer-side interview when it was said that "*If you look at their products … most of its acquired. Their engineering capability is not great … good at the stuff they know, but not if asked to do anything different*". This mind-set and bias may have remained unabated when compiling the supplier scorecards. However, more empathy may have been introduced when conducting my interviews. Compared to others in the cohort of twenty-four suppliers on the SD/DT programme, this bias may have been more pronounced for Foxtrot as the most extreme case of a "*taker*".

	Foxtrot (Successful outcome at Waypoint B, but relative absorptive capacity of AC4 in 2019Q4 does not triangulate with this)
Prior to Waypoint A Change agent feedback form (supplier-side)	**What are your key takeaways?** *"change management with Operations is a key success factor … business set-up and governance to deploy digital solutions into [our many facilities]."* **What help do you need as your firm's change agent?** *"business case is another key success factor and challenging to track … further information on the value creation for [description of their type of firm]."*
Waypoint A Buyer-side interview	**Compromise** *"When we last spoke about [firm name] … we'd started to talk to them about technology development ideas and then, all of a sudden, they re-organised their businesses. They completely took their eye off the ball. They focused on everything internally in the organisation. The customer came second fiddle and everything just went pear-shaped … Digital, they say it's a big thing, but I don't think they'll see it as a big thing with their customers. I think they'll see it as a big thing with their facilities."*
Waypoint B Supplier-side interview	**Learning** *"This is an area where there are so many unanswered questions and, I mean, I keep discovering at all levels that nobody has the magic bullet and nobody even pretends to having the magic bullet."* **Internalising** *"I'm happy to say that we had a kick-off call around the digital minimum standards formal assessment earlier this week with all the people who were identified as the logical owners for the individual chapters. They all very openly said, you know, 'Absolutely, that's my territory. I'll own that. I'm taking that forward.' … I think we moved from all observing and understanding, which is where we were very much at the end of last year, to actually setting ourselves to work on it. The difficulty, of course, is there's one thing having clear owners at the group level and another being able to drive that change to the operational businesses where it needs to eventually materialise. But at least we have the change agents, I think, at the group level. Which is good."* **Sharing** *"It depends on where you sit on the maturity curve because, I think, we're … learning what the right way of deploying some of this capability is. So we feel that we've got nothing to lose from sharing and collaborating at this point. I think if we were much more mature and we felt that we had a bit of an advantage because we were that mature, then it might be a different conversation. But we're not there yet and we've probably got a little way to go before we consider ourselves for that level of maturity."*

Figure 6.7: Quotes from, or about, Foxtrot at waypoints on the SD/DT programme

6.2.2 The case of the giver (Indigo)

Next, I review the case of Indigo in order to explore aspects which are special, or unique, about them which may have led to a lack of triangulation in my results. Indigo were judged to have a successful outcome at Waypoint B, but their relative absorptive capacity at 2019Q4 of AC3– (as measured through the supplier scorecards) did not triangulate with this. It can be seen from Appendix A that their operational scorecard has been up and down. If the assessment had been taken at 2019Q3 or 2019Q2 then they would have been AC4, like Foxtrot. This would have pointed even more strongly to an unsuccessful outcome. However, they are a different case to Foxtrot in that the buyer/supplier relationship is on a much stronger footing. They are classified as a growth supplier. Lots of new work is being placed with them by the buyer; however, with this comes promises and expectations.

An important aspect of consideration which may have contributed to the lack of triangulation is that Indigo were the most extreme case of a "giver" from the cohort of twenty-four suppliers on the SD/DT programme. Grant (2013) includes in his attributes and characteristics of a giver that they have "*unique approaches to interaction in four key domains: networking, collaborating, evaluating, and influencing*". This is certainly true for Indigo in terms of one of their staff members. The person that they nominated to lead for them on the SD/DT programme had a wealth of these attributes. However, during busy times, his firm lacked the necessary bandwidth and strength in depth.

Figure 6.8 shows quotes from, and about, Indigo which were taken on three occasions during the SD/DT programme in a similar manner to those shown previously for Foxtrot. A very different tone is apparent between Foxtrot and Indigo. My reason for characterising one as the taker and the other as the giver becomes more vivid. Indigo's response on the change agent form was typical of their representative. Only two others in the cohort (15% of the returns) turned the question around to explicitly state what they themselves were going to contribute.

However, similar to Foxtrot, a potential reason why my results did not triangulate for Indigo may come down to measurement bias and subtle differences in the management of expectations. The specifics for Indigo being that those compiling the supplier scorecards were growing impatient and seeking tangible quick wins. Their expectations were linked directly to the award of new business and using technology swiftly to support the industrialisation and ramp-up. But, my interviews were less confrontational and were tempered by the more voluntary nature of the SD/DT programme.

	Indigo (Successful outcome at Waypoint B, but relative absorptive capacity of AC3– in 2019Q4 does not triangulate with this)
Prior to Waypoint A Change agent feedback form (supplier-side)	**What help do you need as your firm's change agent?** *"Nothing at this point.* *I will support you on the roll-out of the new [name of digital tool]."*
Waypoint A Buyer-side interview	**Acquiescence** *"[Firm name] are going through a large company change at the moment … we are really keen to move forward and do the [digital] minimum standards … although we did an early trial … we want to see it moved to a proper roadmap now and to see them develop their capabilities … my only worry is its always just [employee name] … he's the senior guy … but why isn't he delegating more?"* *"I'm getting frustrated with [firm name] as they seem to talk a lot about future capabilities but are not acting on the here and now … if it's not [employee name] there is no backup for their work on the digital minimum standards."*
Waypoint B Supplier-side interview	**Innovating** *"… a way of thinking digitally and thinking agile, fast change, and not being afraid to try something … and fail things too. We wanted to do the [digital tool], it didn't quite do what we wanted it to do. It was too big, and so we learned what not to do which was equally as important … we gave it a try and so we know why it's difficult. So, for me, that's value in itself, the willingness to do it."*
	Contributing *"You [Rolls-Royce] became an oil tanker … you can actually hop in a speed boat off the tanker, go out and explore a bit, and then help set a course on which way we want to go … so I think that for me to be part of that and to be able to help contribute and shape things such as [the digital] minimum standards [has been very rewarding]."*
	Developing *"There is never a status quo balance … you want to be pushed, you want to be challenged, you want to be taken out of your comfort zone."*

Figure 6.8: Quotes from, or about, Indigo at waypoints on the SD/DT programme

6.2.3 The case of the laggard (Juliet)

Finally, I review the case of Juliet in order to explore aspects which are special, or unique, about them which may have led to a lack of triangulation in my results. Juliet were judged to have a successful outcome at Waypoint B, but their relative absorptive capacity at 2019Q4 of AC3– (as measured through the supplier scorecards) did not triangulate with this. It can be seen from Appendix A that timing may have played a role here, because they are a far more marginal case than Foxtrot or Indigo. They were AC1 for the vast majority of their time on the SD/DT programme which, had it continued, would have resulted in my results triangulating for them.

This again raises the possibility of measurement error, bias, or phasing in the triangulation of my results. Intriguingly, concerns about the supplier scorecards were raised by Juliet in their supplier-side interview. They were the only firm to explicitly do so. They said: *"I think there's a misalignment in the level of interaction with digitisation on both sides when we meet to discuss the scorecard … [Rolls-Royce personnel] focus on the hard metrics, quality and delivery, and this dominates the discussion … [those discussing are] nowhere near the required level of understanding [about digital] … there's a general lag in terms of the strategic direction."*

Buyer staff are intended to play a role in pointing their suppliers in the right direction and drawing in experts and support if required. An early cry for help can be detected in the change agent response from Juliet in Figure 6.9. This may be where unique problems have arisen with them which could have contributed significantly to their results not triangulating. The organisational design on the buyer-side is very different for Juliet compared to most others in the cohort. There is less immediate and direct support available for digital manufacturing to either the supplier or to the buyer staff who work with them. My results are less likely to triangulate in circumstances where one input is derived from staff blindly going through the motions of tracking deliverables (i.e. the supplier scorecards), and the other probes deeper to grasp the full context (i.e. my interviews).

Figure 6.9 shows quotes from, and about, Juliet which were taken on three occasions during the SD/DT programme in a similar manner to those shown previously for Foxtrot and Indigo. When comparing them, it is possible to surmise that Juliet's issue may be more with their own "absolute" level of absorptive capacity rather than that associated with their relationship to the buyer (i.e. not their "relative" absorptive capacity).

Finally, another consideration which may have contributed to the lack of triangulation is that Juliet were the most extreme case of a "*laggard*" from the cohort of twenty-four suppliers on the SD/DT programme. Rogers (2003) places laggards as the last to adopt an innovation and highlights that they tend to be more suspicious of change agents. In terms of my engagement and diffusion model in Figure 5.2, Juliet sit at Level 2 whereas Foxtrot and Indigo are at Level 1. In this respect, Juliet are a laggard compared to many others in the cohort. Their delay (or compromise) in adoption may also have been aided by the power regime (i.e. supplier dominance); but, now they have less wriggle room with the launch of the digital minimum standards.

	Juliet
	(Successful outcome at Waypoint B, but relative absorptive capacity of AC3– in 2019Q4 does not triangulate with this)
Prior to Waypoint A Change agent feedback form (supplier-side)	**What help do you need as your firm's change agent?** *"make it a focused or designated role at my firm"* and *"examples and role models from other firms who have tackled all levels and functions across multiple facilities."*
Waypoint A Buyer-side interview	**Compromise** *"The structure of [firm name] is flat. They're nowhere near the size of a corporate organisation … don't have an army of people … now that they've got the right people engaged, I think they're almost acquiescence … their issue is one of IT capability … when we did the draft [digital] minimum standards with them last year they were very honest and open about it, a bit self-deprecating in a way, but they weren't scoring very highly and they recognised that … [they] are a very technologically driven company … but that's very much on their product development and technological arm, not in the operational plants … I think we've seen a bit of compromise. Because, again, it's just limited points of contact and bodies and they've got other jobs to do. It's sort of beg, borrowing, stealing time and availability … They don't have the corporate infrastructure to support it."* *"I spent quite a bit of time recently with [firm name] …. and their new general manager [employee name] who has a [digital] background but is currently struggling with lower level [operational] issues … but is keen to be looking forward as well … they don't seem to have a corporate strategy on how to move forward so suspect a few point trials might start to feed the desire."*
Waypoint B Supplier-side interview	**Aligning** *"Being involved has enabled me certainly to have dialogue internally in the company about what direction we should go in. The company was initially kind of overwhelmed with the number of choices."* **Customising** *"We're still creating our digitisation framework. We're trying to customise our position where possible to include our customers' requirements … we remain quite agile and steer digitisation where we think it will give us the biggest bang-for-the-buck … we can't digitise everything … we probably need to bring it together through some kind of plan specifically on digitisation and that is the bit I would suggest is probably lacking at the moment."* **Understanding** *"I'm not sure where we really want to go. I'm not sure whether we know. So, I sort of see us really as just understanding what other people are doing, which drew me straight into the benchmarking element. And then really from there, understanding what we've got and what we would need to develop … we're still looking to hire a digitisation expert or a lead … our intention is to make sure as we do develop our digitisation plan and approach that we're aligned with our key customers."*

Figure 6.9: Quotes from, or about, Juliet at waypoints on the SD/DT programme

6.3 Summary of key implications from this chapter

This section begins by comparing my results with the research from others. Then, I summarise the business contribution. Finally, I summarise the academic contribution and identify items for discussion in chapter 7.

6.3.1 Comparing my results with the research from others

In section 2.4.1, I explain that there is little research on the success of SD programmes for purposes such as my own. Where data is available, it suggests that digital transformation (or equivalent) is the least influenced. Furthermore, scholars find one derivation of SD to be unsuccessful and to quickly stagnate (CoI: section 2.3.2). Looking more broadly, McKinsey (2018) speak for many when they find repeatedly through annual surveys that success levels of no more than 30% are common for large scale organisational change. Here, they define success as one that improves performance and also equips the firm to sustain these improvements over time.

However, I am wary of comparing my results with others with this regard. Mine is not the type of empirical research which seeks to generalise or draw statistically grounded conclusions. Instead, I will return to the source of my theoretical framework for Waypoint B in Figure 3.9. The framework shows the sharing of best practice which, in my case, was achieved through the digital minimum standards. But, also in their article on the fusion between institutional and organisational learning theory, Chandler and Hwang (2015) point to the important role of absorptive capacity. They argue that it demonstrates "*an ability to learn and provide the freedom for organisations to cast a wide net in the search for new ideas because they are better placed to absorb the knowledge and transform (or customise) the practice on arrival ... In fact, those firms that engage in the maximum amount of learning and search are likely to find more unique and advantageous innovations to adopt the further they venture from their local environment and established methods of operation*". They call for more empirical research which I have provided through my attempt to operationalise and measure absorptive capacity. I will discuss measurement bias and how it might be addressed in chapter 7.

6.3.2 Business contribution

I will keep this brief to save repetition with section 5.3.2. That which is better placed here, however, is the contribution which my research has made to the supplier scorecards used by Rolls-Royce. Again timing helped. They were due an overhaul and aspects other than my own were covered. But, pace and depth of enquiry can be very different between business and academia. I will touch further on this in section 7.3. I am certain that the update of the supplier scorecards benefited from my research and they have embarked upon a radically different path than would otherwise have been the case.

Finally, in terms of the business contribution, I shall return to the word "*aligning*". My buyer-side interviews prioritised it as the outcome which they wished to see from the SD/DT programme and, therefore, it featured highly in the success criteria (Figure 4.7). My supplier-side interviews then selected it as the most popular word from thirty-five in my response framework (Figure 6.6). This echoes back to the views of Krause and Handfield (1999) who remarked about SD that "*the final objective is to achieve a globally aligned supplier network*". Yet, in practice, Krause and Handfield found that "*even the most advanced organisations interviewed in this study had yet to achieve this level of integration.*" My research suggests that Rolls-Royce are heading in the right direction.

6.3.3 Academic contribution and items for discussion in Chapter 7

The academic contributions which I have made in chapter 6 can be summarised as:

a) Triangulated evidence to show that the SD/DT process can answer the research question (i.e. how to develop suppliers within an extended enterprise towards a digital enterprise) for "*cases within a case*" (Gehman et al, 2018) in the aerospace sector. The empirical results have shown that my organisational change process has a high success rate (18:24 suppliers) together with high potential (21:24 suppliers) to be operationalised and embedded through the supplier scorecards.

b) Supported the fusion of institutional and organisational learning theory through empirical research. Developed a response framework with a rounded dyad-level perspective (Figure 6.6).

c) Advanced the operationalisation and measurement of relative absorptive capacity using a novel approach, supplier scorecards. Chapters 7 and 8 discuss measurement bias and further work.

DISCUSSION

Exploring the implications of my results and how they were obtained

Chapters 1 and 2 set the scene and synthesised process-steps for organisational change from literature. Chapters 3 and 4 constructed a theoretical framework and introduced my research methodology. Chapters 5 and 6 provided the empirical results which show that my process can answer the research question. It has a high success rate together with high potential to be operationalised and embedded through the supplier scorecards.

Now, chapter 7 discusses the implications of my results. This chapter is divided into three sections from 7.1 to 7.3. First, likely sources of measurement bias in the supplier scorecards are reviewed together with their means of attenuation. Second, perceived attributes of the digital minimum standards are reviewed and their continued use. Finally, my own experience of work-based research is discussed. A bullet-point executive summary is given overleaf for those who prefer this format.

Section 7.1: **Discussion about three sources of measurement bias**

- Chapter 6 reveals potential for supplier scorecards to be used to operationalise and measure relative absorptive capacity; however, there are 3 instances which suggest the presence of measurement bias.

- Foxtrot's supplier scorecard assessment may have been subject to common measure bias.

- Indigo's supplier scorecard assessment may have been subject to negativity bias.

- Juliet's supplier scorecard assessment may have been subject to ambiguity bias.

- Attenuating these sources of bias could be pursued by training and systemising the mundane transactional elements of the assessment process.

Section 7.2: **Discussion about the digital minimum standards**

- There is reason to believe that the digital minimum standards will continue to be perceived positively. This conclusion is reached by assessing them against the 5 perceived attributes of an innovation (Rogers, 2003).

- Concerns over awareness bias, coupled with the still early stage of adoption and diffusion, result in the digital minimum standards remaining unchanged for the time-being. For 2020, the focal firm focuses instead upon training and embedding.

Section 7.3: **Discussion about work-based, part-time, research conducted by a mature student**

- As a part-time student, I experienced what some have reported as a sense of standing between two very different worlds (i.e. industry and academia). There is a different pace and rhythm. I found the experience to be very enriching and positive for myself personally and also for the success of the SD/DT programme.

- As a mature student, I believed that I had already honed many skills after nearly 40 years of problem solving in industry. However, I benefited significantly from taking time to read more deeply around a subject, to fully analysis and review data, and most importantly to pause to reflect in a more structured manner.

- My advice for those who follow is that you have to be prepared to "*make the road by walking*" (Gorinski and Ferguson, 1997).

Paul Hacker, PhD thesis, University of Cambridge, May 2020

7.1   Discussion about three sources of measurement bias

The results in chapter 6 show some potential for supplier scorecards to be used to operationalise and measure relative absorptive capacity; however, there are also instances revealed which suggest the presence of measurement bias. The sources of bias which scholars have previously identified in balanced scorecards include: negativity (e.g. Kaplan et al, 2012), ambiguity (e.g. Liedtka et al, 2008), and common measure (e.g. Lipe and Salterio, 2000):

- Negativity bias refers to situations where there are equal measures of good and bad present, but the psychological effects of the bad outweigh those of the good. There are indications that negativity bias may be present in the supplier scorecard assessment for Indigo (section 6.2.2).

- Ambiguity bias occurs with individuals who are intolerant of ambiguity and they discount, or ignore, such information regardless of its potential significance. There are indications that ambiguity bias may be present in the supplier scorecard assessment for Juliet (section 6.2.3).

- Common measure bias occurs when decision-makers are unwilling to incorporate information which is less familiar to them, because it requires greater cognitive effort to process. This may result in them reacting to lagging measures (i.e. those for which they are familiar) as opposed to working pro-actively through the leading measures (i.e. those for which they are less familiar). There are indications that common measure bias may be present in the supplier scorecard assessment for Foxtrot (section 6.2.1).

Balanced scorecard assessment is recognised as a highly complex task. Hence, the topic of training is often raised in literature as a primary means of attenuating bias (e.g. Dilla and Steinbart, 2005). The training and awareness APP for the digital minimum standards (Figure 5.4) was designed with the intention of it being intuitive and able to be cascaded to others through a train-the-trainer approach (buyer-side and supplier-side). Section 7.2 discusses the digital minimum standards in more detail.

Another means of attenuating bias in balanced scorecard assessment is effort-related (e.g. Libby et al, 2004). At present, the process being followed is a bit of a chore and this was raised with me on a number of occasions. There are plans to systemise it within an eProcurement digital tool, called DPEX, and this is one of the activities being pursued in 2020 by the firms on the SD/DT programme.

7.2   Discussion about the digital minimum standards

Section 5.3.4 introduces two items for discussion. Firstly, whether potential adopters will continue to have good reason to perceive the digital minimum standards positively. Secondly, whether the standard should be increased or remain unchanged for the time-being. Furthermore, section 7.1 highlights the need to discuss a third, and interrelated item, that of training.

Diffusion of innovation (DOI) theory provides a means by which the first item can be explored. In DOI theory, Rogers (2003) lists the perceived attributes of an innovation as its: relative advantage, compatibility, complexity, trialability, and observability. Therefore, I shall review each of these in turn for the digital minimum standards:

a) ***Relative advantage:*** Rogers defines this as "*the degree to which an innovation is perceived as being better than the idea it supersedes*". The quote from Delta about benchmarking (Figure 6.5) captures aspects of this in that the digital minimum standards provide them with a means of benchmarking which had not previously existed. They are given free-of-charge to all suppliers and, furthermore, they help them to then make their own assessment of the functionality and economic profitability of different digital technologies. It is too early to assess the impact of the digital minimum standards upon over-adoption (i.e. adoption of certain digital technologies by a firm when independent experts feel they are needless and should have been rejected). However, there is some evidence that discovering and prioritisation is important to the adopters (e.g. Bravo in Figure 6.5). The growing mandate to adopt from the focal firm is clearly prevalent, although there is no evidence from any of my interviews of social prestige having been a factor in adoption.

b) ***Compatibility:*** Rogers defines this as "*the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters*". The quote from Foxtrot about internalising (Figure 6.7) captures aspects of this in that the digital minimum standards provide firms with an implementation framework. They were co-created, trialled, and refined with the suppliers on the SD/DT programme. This is likely to have contributed significantly to their compatibility. Nevertheless, there is still room for improvement. The quote about Indigo's acquiescence (Figure 6.8) shows that full support and engagement was not always possible during their development. But, further updates and iterations of the digital minimum standards will occur over the coming years as part of an ongoing continuous improvement programme.

c) **Complexity:** Rogers defines this as "*the degree to which an innovation is perceived as relatively difficult to understand and to use*". The quote from Juliet about aligning (Figure 6.9) captures aspects of this in that the digital minimum standards are used as one of the prime means of communication. In Figure 5.1, guidelines 5.ii and 7.ii give the team mantra which was "*working together to find our way through the digital fog*". Of critical importance here is that the digital minimum standards provide a common vision and vocabulary (guideline 8.i) which is intended to carry through all of the organisations at firm-level, dyad-level, and network-level.

d) **Trialability:** Rogers defines this as "*the degree to which an innovation may be experimented with on a limited basis*". The quotes from Indigo about innovating (Figure 6.8) and Quebec about testing (Figure 6.5) capture many aspects of this. Also, in Figure 5.1, guideline 7.i refers to the concepts of sprinting and the minimum viable product. The training and awareness APP for the digital minimum standards is free to download and is designed to be easy to explore.

e) **Observability:** Rogers defines this as "*the degree to which the results of an innovation are visible to others*". The quotes from Uniform about explaining (Figure 6.5) capture aspects of this in that the digital minimum standards are used as one of the prime means of communication. In Figure 5.1, guidelines 9.i and 9.ii refer to the integration of the digital minimum standards into the overarching supplier performance management process. At workshop 20, they were used to showcase best practice and current status to approximately 100 firms from across the Extended (Digital) Enterprise.

Thus, there is reason to believe that the digital minimum standards will continue to be perceived positively. Firms have not identified any conflict with the requirements or activities from their other customers. Moreover, a few of their other customers have recently enquired (tentatively) about working closer together on common aspects which support their own movement towards a Digital Enterprise. The intent being to benefit industry as a whole rather than to provide any specific firm with unique competitive advantage.

Moving next to the second item for discussion. Should the standard be increased or remain unchanged for the time-being? I reviewed this in detail with my steering group (section 4.2.1). In summary, the decision was made to: keep it unchanged for 2020; use the firms on the SD/DT programme to investigate potential changes during 2020 for earliest implementation in 2021; and focus the remaining resources in 2020 upon upskilling and embedding.

A key consideration in making the decision summarised above was to respond to awareness bias. This is another source of bias in addition to the three already discussed in section 7.1. Awareness bias has been found in environmental health research when more illness is misreported within proximity to a known potential hazard (Moffatt et al, 2000). Bias can arise from increasing knowledge, understanding, and awareness. A further permutation which has been found in the gas process industry is described by Ellis (2018) as the "*watermelon effect*". Here, he warns that bias can also arise from a lack of awareness. He points to the risk arising from a superficial use of metrics and dashboards. A green (positive) colour on the outside which is poorly founded; but, remains unchallenged, because it is not highlighting an issue of concern on the dashboard. However, it masks a red (negative) colour on the inside. This is the true position, but it can only be revealed through deeper enquiry and/or with better training.

Members of my steering group had first-hand experience of awareness bias and, therefore, argued not to raise the bar at present on the digital minimum standard. All staff are yet to be trained and the baseline is only partially established and embedded. They forecast that 2020 may see a decline in the results as awareness increases; however, this is to be celebrated if it leads to an accurate reflection of reality which can then be securely built upon. One person reflected that awareness bias is a long term phenomenon: "*The more aware you become, the harder you tend to mark yourself.*"

This takes us to the final item of discussion for digital minimum standards which is that of training. A computer-based APP was used for their launch (Figure 5.4); however, going forward, more video streaming from the shop floor is envisaged. The aim is to stimulate collective learning as described in section 2.3.1c with 'virtual' communities of practice and 'chat rooms' with subject matter experts. A training and support model which is strongly aligned towards the principles of a Digital Enterprise (Figure 1.4). This, of course, is reliant upon a suitable business case. Gaining a better understanding of the whole value proposition is included in the recommendations for further work in chapter 8.

Paul Hacker, PhD thesis, University of Cambridge, May 2020

7.3 Discussion about work-based, part-time, research conducted by a mature student

My research was performed internationally, but organised and led from the UK. I began the research against the backdrop of the Made Smarter Review (UKG, 2017). This argued that UK businesses were facing a skills shortage, particularly in digital engineering capabilities, and were being hindered by a fragmented skills system and a lack of systematic engagement between industry and academia. This built upon the recommendations of the Dowling Review (UKG, 2015) which recommended increasing the permeability of the interface between industry and academia in order to promote stronger and more effective, trust-based, relationships.

Methodological route proving is listed in section 1.5 as one of my research objectives and I explain my contribution in section 8.3. According to Costley et al (2010), work-based research is a relatively new field of study which is still creating and understanding methodologies. Furthermore, my firm kindly funded me to perform the research as a trial for part-time, later career, mature students. In my submission for funding and support, I argued that later career workers are just as motivated to spend time and effort on their own professional development as younger workers. Their interests and aspirations, rather than their age, are the key differentiator (Greller, 2006). Also, firms and research bodies can benefit by drawing upon the talent, creativity, experience, and networks acquired by these workers from their preceding industrial careers.

My research was performed as a part-time PhD as opposed to an EngD programme. The latter was launched in the UK in 1992 in response to criticism that the traditional PhD programme lacked industrial relevance (Parnaby, 1990). I previously served as an EngD industrial supervisor and I subsequently found many similarities with my own form of research. Kitagawa (2011) describes a sense of standing between two very different worlds (i.e. industry and academia). In his survey, one EngD student commented "*Applying academic theory in a business setting is difficult. You have to show immediate financial return or the company is not interested*." Another added "*It is hard to keep the academic and industrial needs balanced. The problem keeps changing as the company changes, so it cannot readily be fully expressed*." My own experience, however, was overwhelmingly positive. There certainly is a different pace and rhythm derived from standing between the two very different worlds. But, overall, I found it to be very enriching and positive for myself personally and also for the success of the SD/DT programme.

As a mature student, I believed that I had already honed many skills after nearly 40 years of problem solving in industry. However, I benefited significantly from taking time to read more deeply around a subject, to fully analysis and review data, and most importantly to pause to reflect in a more structured manner. Many friends and colleagues have since observed that my enquiry and thought processes are now very different. I searched for a quote to symbolise how I have changed and settled upon the following from Easton (2000). He sets the benchmark for research into industrial networks which I strived to live up to: "*to be inquisitive, to look for the roots of things, to disentangle complexities and to conceptualise and reconceptualise, test and retest, to be rigorous and creative and above all to seek for the underlying reality through the thick veil which hides it*."

But, I have also grown to better appreciate that work-based research is not for everyone. You must be incredibly well organised and disciplined. Bentley (2012) sets a sombre tone in his PhD application handbook by stating that "*Most universities prefer not to take on too many part-time PhD students because statistically, the success rate is very low. With reduced access to the university facilities and staff, distractions from work, and so many years in which to lose motivation and direction, most part-time students give up and never achieve their PhDs.*"

Nevertheless, despite its challenges, my own experience is such that I prefer to pass on the advice from Gorinski and Ferguson (1997) to others considering this path. They summed up action research by saying that you have to be prepared to "*make the road by walking*".

Chapter 8

CONCLUSION

Explaining my contribution and recommendations for further work

Chapters 1 and 2 set the scene and synthesised process-steps for organisational change from literature. Chapters 3 and 4 constructed a theoretical framework and introduced my research methodology. Chapters 5 and 6 provided the empirical results and showed that my process can answer the research question. Chapter 7 discussed the implications.

Now, chapter 8 concludes with an overall summary followed by a description of my research contribution and recommendations for further work. I contribute to knowledge through my process for heterogeneous organisational change. Also, I make a work-based methodology contribution.

8.1　Concluding summary

I have answered the research question by demonstrating that the SD/DT process can be used to develop suppliers within an Extended Enterprise towards a Digital Enterprise. These heterogeneous interfirm organisational structures are complex. There are aspects of wickedness which have to be tackled through the process of organisational change. The firms, and also the digital technologies, are at various states of readiness for deployment; but, change is often needed in unison. Bringing them together to reach a successful enterprise-wide solution is crucial, yet firms may not always agree on even the most basic of principles. There is a dichotomy. The ability of firms to choose how they respond to organisational change – versus – the need for sufficient firms to respond positively if the collective vision of a Digital Enterprise is to be realised.

The SD/DT process did not pre-exist and, therefore, I created an initial version by synthesising and integrating literature from multiple domains and sources. I then iterated, refined, and recorded it through a series of action research cycles which coalesced around 21 international workshops held over a 3-year period. I ultimately captured and documented the SD/DT process using 9 steps, 28 guidelines, and 4 categories of special intervention. I used a steering group and expert panel to guide my research and validated my final SD/DT process documentation with 4 other parties.

I studied the application and outcomes of the SD/DT process upon a diverse cohort of 24 firms. Their 7 contextual factors spanned those revealed by literature to have most potential significance, such as: their relative absorptive capacity and the link between hierarchy and causal power. I developed a novel approach to measure relative absorptive capacity through the proxy of their supplier scorecards. This was the only contextual factor to change over the 3-year period of my research and my novel approach allowed quantitative data to be gathered independently.

Using institutional and organisational learning theory, I set 2 waypoints to assess progress on the journey from an Extended Enterprise towards a Digital Enterprise. I conducted nearly 100 interviews, covering both sides of the buyer/supplier dyad, and developed a response framework to explore each firm's purpose in being on the SD/DT programme. This deepened insights, because the terminology otherwise used in theory held negative connotations in a business setting. I established success criteria, which were ratified by my steering group, and used them to assess the final outcome of all 24 firms in the cohort. My own assessment was counterchecked and agreed by another person.

I found that many firms had a successful outcome (18 out of 24) and, therefore, this demonstrated that the SD/DT process can be used to answer my research question. Also, in most cases (21 out of 24), regardless of whether the firm's outcome is successful or not, the supplier scorecards and, therein, the proxy for their relative absorptive capacity predicted a consistent result. Each firm had its own nuances and I revealed how a web of contextual factors contributed to their outcome. But, in most cases, the overall net effect as it relates to the SD/DT programme was captured consistently through their supplier scorecards.

This has promising implications for the sustainment of the journey towards a Digital Enterprise and for its incorporation into routine business. There are 3 key parts to this argument. Firstly, a process has been created which has been shown to have a good success rate across a diverse mix of firms. Secondly, the aerospace sector which I am researching is mature and stable. Hence, in most cases, only 1 contextual factor of note is likely to be able to be changed for firms in an Extended Enterprise. This is their relative absorptive capacity. Thirdly, a proxy for measuring this through their supplier scorecards has been shown to be effective in the majority of cases. Supplier scorecards are routinely used across industry as part of an overarching performance and relationship management process.

Therefore, I investigated the reasons why the supplier scorecard did not predict in accordance with actual outcomes on 3 out of 24 occasions. I refer to these cases as those where my results do not triangulate. The firms in question are Foxtrot, Indigo, and Juliet. I characterise them as taker, giver, and laggard respectively to highlight their behavioural differences. I reveal evidence which points to measurement bias in each of their supplier scorecard assessments. I trace the potential sources to common cause, negativity, and ambiguity respectively. Literature shows that these sources of bias may be attenuated by training and the systemisation/removal of mundane tasks. Thus, these actions are now being pursued as part of the ongoing programme of work which continues after my research.

Also, during my research, an instrument emerged for the sharing of best practice which proved to be pivotal to diffusion and organisational adoption. This is in accordance with my theoretical framework which is based upon a recent fusion of institutional and organisational learning theory. The instrument which emerged is called the digital minimum standards. There is already some indication of diffusion with over 200 user requests to the training APP after only 7 months of full release; however, it is still very early days.

Using diffusion of innovation theory, I show that there is reason to believe that the digital minimum standards will continue to be perceived positively. Nevertheless, some broader concerns over awareness bias are raised by the focal firm and, therefore, their focus for the time-being remains upon training and embedding the standard. They decide not to start to raise the requirements threshold for the level of adoption by firms within the Extended Enterprise until at least 2021. There are currently 10 firms who report that they have achieved the standard, and 39 in total who are actively adopting them; but, not all self-assessments have yet been fully validated with the focal firm.

Overall, my research has had a positive business impact. Research ended partway through the final step of the SD/DT process. All that remains for completion is the longer-term embedding into executive systems and controls, such as the Quality System at the focal firm. When my research ended, the project portfolio was healthy with a strong gearing of investment: 6 live projects, 3 completed projects, 1 cancelled project, and 1 new project in the hopper ready to be launched. In 2019, supply chain readiness was achieved for digital product definition across Rolls-Royce's aerospace product base and they won a top industry award for their submission on creating collaborative supply chains. In 2020, there are plans to launch another regional cluster group and a further cohort in a different business sector.

Thus, a solid platform has been established. However, 3-years to get to this stage is a long gestation period for business which often requires quicker financial returns. Furthermore, it remains uncertain how business value will continue to be extracted and to grow. This is an intriguing area for further research. Organisations such as the World Economic Forum have published estimates of significant financial returns for Digital Enterprises, but many key questions remain e.g. if/how joint investment should be tackled at enterprise-level and firm-level. This and other recommendations for further work are described in section 8.4.

8.2 Contribution to knowledge

My research sits within the domain of organisational change. The supplier development for digital transformation (SD/DT) process which I have created is original and innovative (e.g. Figure 2.2; CAPS, 2014; Watts & Hahn, 1993). Furthermore, agnostic of the topic undergoing change, my process is designed to tackle the impediments to organisational learning in heterogeneous supplier networks which arise from interfirm competition and conflicts of interest (Lane, 2001). Thus, there are two counts of novelty in my contribution to knowledge.

The content, structure and sequencing of activities in my process are new and important. Previous research was inconsistent with different steps taken in different sequences (Figure 2.2). I show that my process steps and guidelines can be followed in practice to a high level of adherence (Figure 5.6) and that they deliver valuable results (Figure 6.1). Crucially, my contribution builds and embeds the process of organisational change into routine business. This was lacking in previous research (section 2.2.9), but is essential for the ongoing sustainment of major, long term, change programmes. Furthermore, my findings have extended the theoretical framework for supplier development through the unique use of institutional and organisational learning theories for a diverse range of different (contextual) firms.

My process is underpinned by theory, but I have had to take theoretical concepts and operationalise them. A schematic is shown in Figure 8.1. The critical aspects which I have woven into the fabric of my process are: the digital minimum standards for best-practice sharing, and the supplier scorecards for governance via the proxy which they provide for relative absorptive capacity. Best-practice sharing was identified as being pivotal to diffusion and organisational adoption, but empirical evidence was lacking (Chandler and Hwang, 2015). Absorptive capacity has long been identified as important to interfirm knowledge transfer, but difficult to operationalise and measure (Wijk et al, 2011; Roberts et al, 2012; and Lewandowska, 2015). Also, through my research, I have identified four prime sources of measurement bias (i.e. awareness, negativity, ambiguity, and common measure). I have explained how they can be attenuated within my process and revealed insights from operationalisation to feedback and inform theory.

Supplier Development
(Figure 2.2)

Digital Transformation
(Figure 1.4)

CREATION

Step 8 and 9
Grow Results and Embed into Routine Business

Step 7
Deliver Results

Step 6
Operation and Support

Step 5
Programme Launch

Step 4
Supplier Selection

Step 3
Supplier Evaluation

Step 2
Method Selection

Step 1
Strategic Review

SD/DT process
(Figure 5.1)
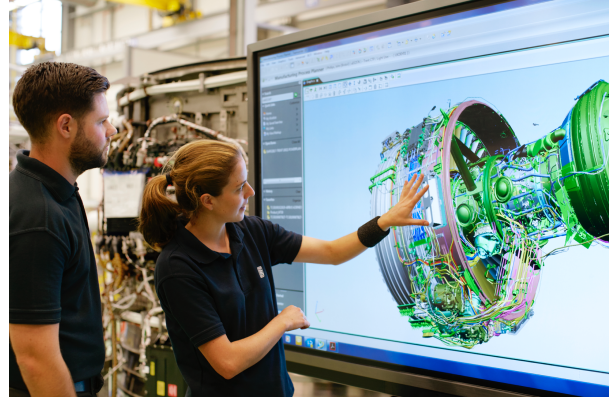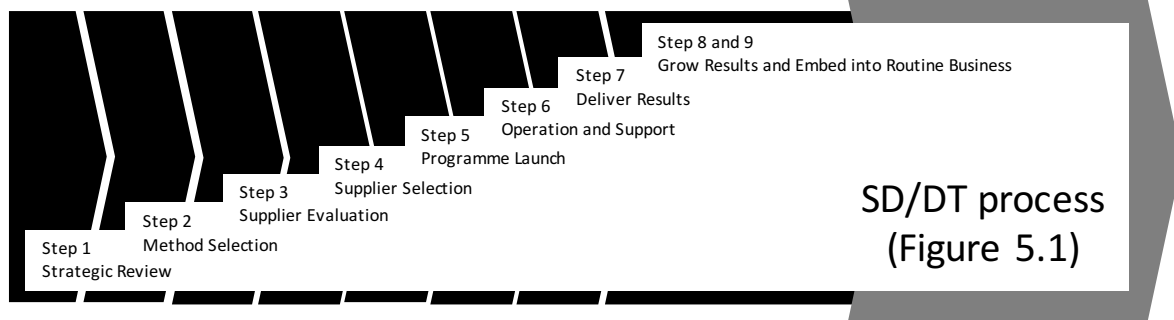
OPERATIONALISATION
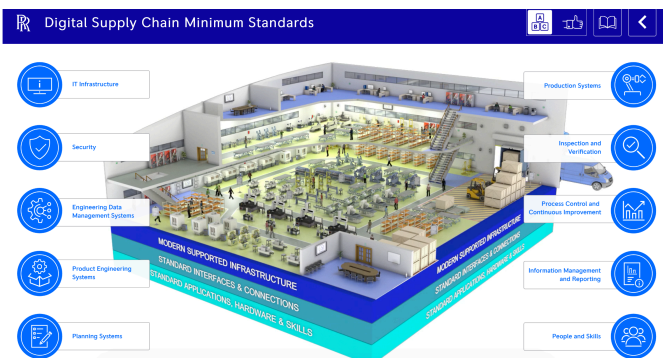
Best-Practice Sharing
(Figure 5.4)

Relative Absorptive Capacity
(Figure 3.7)

Figure 8.1: Schematic of my contribution to knowledge

Paul Hacker, PhD thesis, University of Cambridge, May 2020

There is potential to apply my process elsewhere, but recipients should follow the principles of transferability (Lincoln and Guba, 1985). My sending context includes: the environmental setting (i.e. aerospace sector); organisational maturity (i.e. interfirm experience within an Extended Enterprise); governance framework (i.e. pre-existing balanced scorecards); and the technology era (i.e. up to 2020). A representative from another focal firm in the aerospace sector observed workshop 13 (see Figure 4.3) and has kindly agreed to be cited in my thesis: Colin Scouller, Digital Technical Lead, Thales Land and Air Systems. His feedback on my process was: "*I think it's really good and it can be scaled. You're not going to get much of a bigger scale than yourselves* [Rolls-Royce], *but you can scale down to the likes of ourselves* [Thales]. *We would definitely be able to apply it*." Further research is recommended in section 8.4 to explore the impact upon my process when moving even further away from the baseline established by my research.

8.3   Methodological contribution

Section 8.2 describes the contribution to knowledge which I have made against most of my objectives and the primary research aim (section 1.5). This section now moves onto my final research objective which is to also make a methodological contribution. I have developed a novel approach to conducting work-based research (Costley et al, 2010). Here, the dichotomy which I have successfully addressed is between: (a) gaining sufficient access to be able to study highly commercially-sensitive phenomenon over a long period of time, and (b) being objective and not introducing researcher bias.

Whilst completing this section, I made enquiries within Rolls-Royce in order to establish the latest company position on my domain of research. Third parties are rarely given full access. Accordingly, they only foresaw circumstances where such research was performed by senior, and/or high potential, employees. Thus, confirmation that the dichotomy continues. Furthermore, it was made clear to me that prerequisites would apply for any employee being paid their normal salary to perform this research. In most cases, the methodology would be expected to be interventionist and not observer. A research group could be assembled to bring together a range of skills and perspectives under the framework of a non-disclosure agreement. However, this would become more expensive and would also introduce its own challenges such as maintaining alignment and controlling access.

Having identified the dichotomy early in my methodological design, I thoroughly explored the nature and implications of positionality. I found the continuum from Herr and Anderson (2015) to be particularly helpful. It was from this that I developed my own concept of non-uniform positionality. My interactions with those being researched needed to allow for the important differences in my insider/outsider paradigm. Within Rolls-Royce, for example, my position in global headquarters caused me to be viewed by those in the regional teams as an outsider. Beyond Rolls-Royce, my position in the focal firm posed other risks of bias which I also had to mitigate. I took to keeping track of it in my field notes and journal. Alongside the date and title of each entry, I would pause to describe my positionality ahead of any research interactions. This maintained my guard even when circumstances appeared entirely innocuous. Deeper reflection was also essential which I achieved through my steering group and expert panel (section 4.2). Arranging action research cycles around workshops was invaluable. It gave structure and purpose to our discussions: my findings and personal reflection, followed by independent feedback and reflections, then key actions and next workshops.

Finally, my interview response framework also makes a methodological contribution by virtue of how it was able to be constructed and then applied seamlessly as a result of my rare positionality. The framework is repeated below for ease of reference as Figure 8.2.

	What is your firms purpose in being on the SD/DT programme?				
Group A	Acquiescing	Aligning	Complying	Integrating	Sponsoring
Group B	Avoiding	Buffering	Deferring	Observing	Waiting
Group C	Balancing	Compromising	Customising	Internalising	Translating
Group D	Benchmarking	Developing	Discovering	Learning	Understanding
Group E	Challenging	Defying	Deviating	Resisting	Testing
Group F	Contributing	Explaining	Sharing	Reciprocating	Teaching
Group G	Controlling	Influencing	Innovating	Manipulating	Steering

Figure 8.2: Response framework used for supplier-side interviews (Waypoint B)

(repeat of Figure 4.6 for ease of reference)

My interview response framework is a further example of how I operationalised a theoretical concept in order to apply and use it during my research. I found during my buyer-side interviews that the 5 classic words from institutional theory (Oliver, 1991), which are highlighted in bold in Figure 8.2, had negative connotations in a business setting. Therefore, I collected other words which the buyers used when discussing around the 5 classic words and, for the supplier-side interviews, placed them all alongside each other in a row in neutral alphabetical order as shown in Figure 8.2. Also, I added new rows of words for any new themes which were raised by the buyers (i.e. Groups D and F).

Using the response framework helped to facilitate my interviews and to gather rich data from the suppliers. This is illustrated, for example, by the comments from Quebec in Figure 6.5 about "*testing*" which is the final word in Group E in Figure 8.2. For the interviewee to first broach, and then expand, upon a potentially sensitive subject, such as this, may have otherwise been more difficult/unlikely.

In conclusion, work-based action research allowed me to study highly commercially-sensitive material and to gain deep insights into organisational change over an extended period of time. As an "insider", I succeeded in addressing the risk of researcher bias. It would have been impossible for an "outsider" to have conducted the research. Different approaches and perspectives provide us with a wealth of knowledge. My own helps to complement the weave.

8.4   Recommendations for further work

Three directions for further work are outlined below together with a postscript to reflect upon the COVID-19 pandemic.

a) ***Long-term embedding of organisational change:*** Scholars who studied the move from traditional supply chains to extended enterprises returned to review progress over a decade later (Davis and Spekman, 2004; Spekman and Davis, 2016). Organisational change, of the magnitude which I have described in Figure 1.4, takes considerable time to settle and evolve. Thus, as a consequence of my research, I recommend a long-term longitudinal study into the move to Digital Enterprises over a timeframe of at least double my own. Consideration should be given to the research being performed by an early career, high potential, employee to resolve the dichotomy described in section 8.3. This would provide a different, but complementary, perspective to my own. During such a study, one would expect to see significant advances in the functionality and standardisation of digital technology. Also, other case studies could be gathered to research the long-term embedding of Digital Enterprises across one, or more, industrial sectors.

b) ***In-depth evaluation of the business value proposition:*** During my research, whilst developing a process for major organisational change, it became clear that there is scope for further research into the financing and extraction of value from heterogeneous changes of this complexity. There is a cost/benefit to any change. My research revealed signs that business cases are sought to be constructed and explained in new and innovative ways for Digital Enterprises. For example, one product-centric (traditional) firm enquired about making an investment in return for access to digital data over the product lifecycle. The response, from both sides, indicated research gaps in how to evaluate, optimise, risk assess, and expand to compare this with other options. Levels of analysis to be studied include firm, dyad, enterprise, and government.

c) ***Transferability to different industrial sectors and/or types of organisational change:*** My organisational change process has been shown to be transferable within the aerospace sector for the purposes of digital transformation (section 8.2). However, it may become more stretched and challenged further away from its foundational base. Research could, therefore, study its use and application in different industrial sectors (e.g. construction, retail, etc.) and/or for different types of organisational change (e.g. servitisation, sustainability, etc.).

Postscript: In the opening address at workshop 21, which concluded the fieldwork for my research, the Chief Executive of the host firm requested that participants did not shake-hands in response to the emerging news about the COVID-19 pandemic. We were a large and diverse international gathering who all looked at him with concern and amazement. In the weeks that followed we moved to social distancing and major lockdown. Many lives have sadly been lost.

My research is about major organisational change, however, it was performed at a time without disruption to the global steady-state as has been caused by COVID-19. Nevertheless, what is the role of digital technology in responding to the crisis and does this make the move to a Digital Enterprise more, or less, likely? After a short period of industrial regrouping, my conjecture is that the pace of adoption will increase. Demand, I suggest, will grow from both firms and their employees.

My conjecture that employees will increase their demand for digital technologies stems from the step-change which has been enforced in how we work. In my own firm, for example, the remote working services are now much simpler and more efficient. COVID-19 drove a concentration of effort and purpose to get long-standing issues resolved. Employee expectations and working patterns have now been changed. In my opinion, irreversibly. Employees will not wish to return to old inefficient ways of working. Also, they will grasp the opportunity to rally and to cross the digital divide which has previously slowed the pace of change in the aerospace sector. My argument is not that the challenges of cyber-security and digital non-interoperability will simply go away, but rather that the impetus and forces to fix them will grow: root and branch.

My conjecture that firms will increase their demand for digital technologies stems from their basic quest for survival. COVID-19 has dramatically impacted business, few if any planned for anything like it, therefore the crisis will drive change and be a catalyst for innovation. Deming (1982) offers parallels from far more gradual and orderly times when he describes "*an awakening to the crisis, followed by action*". By comparison, the forthcoming period of change is likely to be swift and chaotic; but, I look here towards concepts such as agility, digital sprints, and the minimum viable product (Figure 5.1 guideline 7.i). Furthermore, organisational structures such as the Digital Enterprise may provide new solutions to how collective groups of firms, perhaps facilitated by their governments, respond to COVID-19 to successfully balance both cooperation and competition. This arrangement is known as co-opetition (Brandenburger and Nalebuff, 1996). And with that, speculating about future interfirm alliances and rivalry feels like a fitting point to end my thesis on organisational change!

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Paul Hacker, PhD thesis, University of Cambridge, May 2020

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Paul Hacker, PhD thesis, University of Cambridge, May 2020

Profiles of the 24 suppliers

in the main study group

Introduction and overview of the contents of Appendix A

To protect their confidentiality, the twenty-four suppliers listed in Appendix A have been renamed using the phonetic alphabet. To avoid confusion, the term Indigo is used (instead of India) and two terms (Mike and November) are omitted. In cirumstances when the supplier has a scorecard with Rolls-Royce, the trend in their results over nearly four years (from 2016Q2 to 2019Q4) is shown using Microsoft EXCEL software. Plotted darkest are the results for the supplier and lightest are the average results for the entire population of suppliers with a scorecard at that particular point in time. The latter, therefore, includes the results for more suppliers than just the twenty-four in my main study group.

A short narrative is provided on each supplier to explain how their scorecard is used to assess their relative absorptive capacity. The assessment is in accordance with Figure 3.6. It uses the status at 2019Q4, and adds a supplementary symbol when the following apply: "+" if the trend in their technology score has been generally increasing since the supplier joined the SD/DT programme; "−" if the trend in their technology score has been generally reducing since the supplier joined the SD/DT programme; and "#" if they had no supplier scorecard (technology) in 2019Q4 and therefore their result was based upon historical evidence and/or an interview with their buyer at Rolls-Royce.

Also, for those with a supplier scorecard (technology) in 2019Q4, then a statement is included in Appendix A in support of the outcome which was measured at Waypoint A/B. As shown in Figure 4.7, data is gathered for Questions 4 and 5 from the scorecard (technology). Question 4: Were the digital minimum standards either achieved by the end of 2019 or a gap closure plan agreed for 2020? Question 5: Are key actions relating to the digital minimum standards captured in the Technology Engagement Plan in 2019Q4?

Paul Hacker, PhD thesis, University of Cambridge, May 2020

Alpha

The relative absorptive capacity of Alpha at 2019Q4 is categorised as `AC2`. They are relatively recent members of the SD/DT programme and, over this period, it is too early to say whether there has been any significance to the small changes in their technology score.

The outcome of the SD/DT process for Alpha at Waypoint A/B is judged to be `successful`. Although they did not achieve the digital minimum standard by the end of 2019, their gap closure plan for 2020 is reasonable. In addition, the actions recorded in their Technology Engagement Plan (2019Q4) are satisfactory.
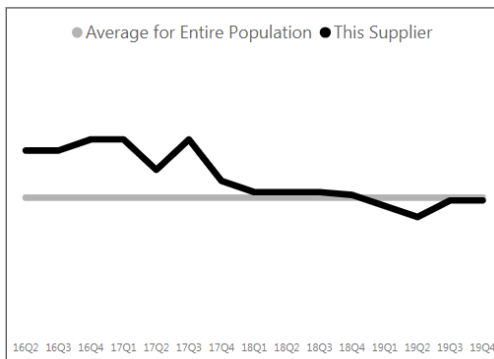
Supplier Scorecard (Technology)
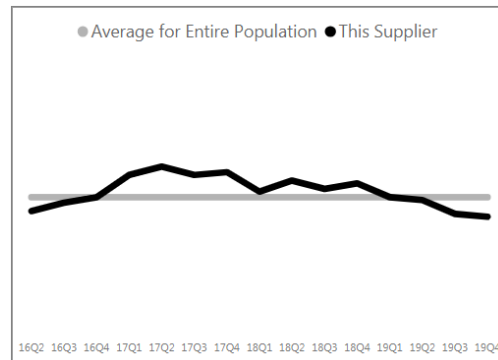
Supplier Scorecard (Operational)

Bravo

The relative absorptive capacity of Bravo at 2019Q4 is categorised as `AC1`. Although consistently performing strongly, their technology score has remained flat since joining the SD/DT programme.

The outcome of the SD/DT process for Bravo at Waypoint A/B is judged to be `successful`. One of their facilities achieved the digital minimum standard by the end of 2019, and the gap closure plan for the other for 2020 is reasonable. The actions in their Technology Engagement Plan (2019Q4) are satisfactory.
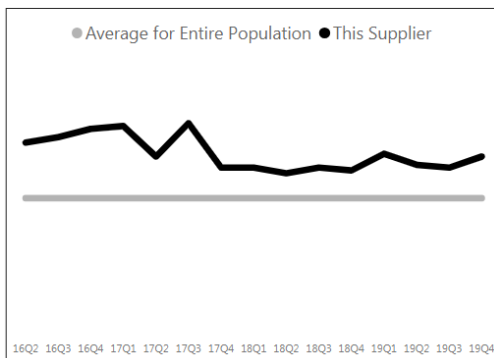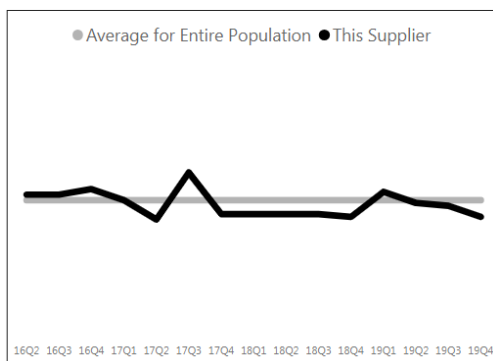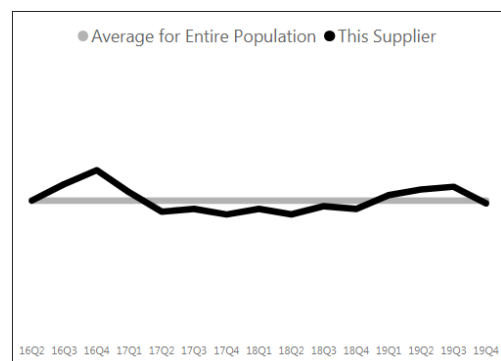

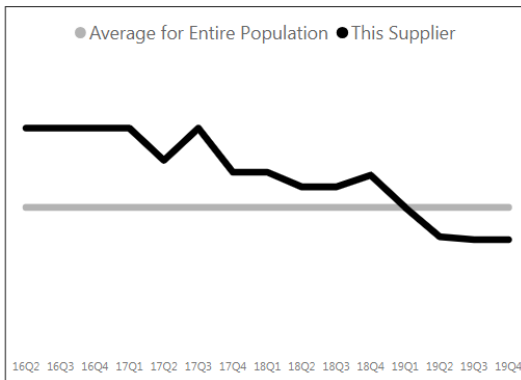**Supplier Scorecard (Technology)**
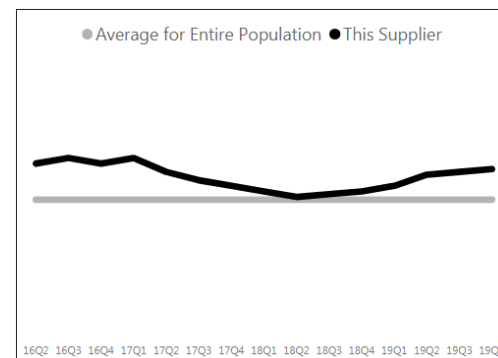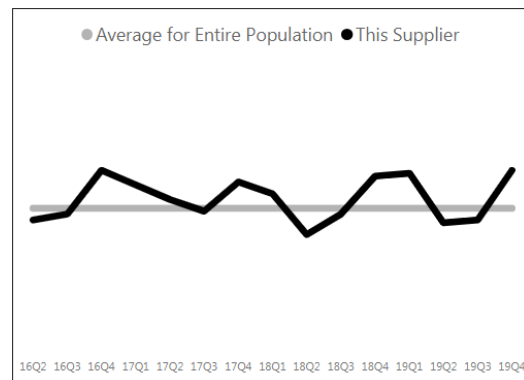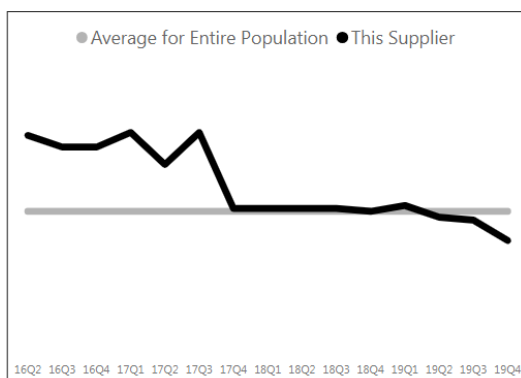

Supplier Scorecard (Operational)

Charlie

The relative absorptive capacity of Charlie at 2019Q4 is categorised as **AC3–**. They are a long term member of the SD/DT programme; but, have a downward trend in their technology score.

The outcome of the SD/DT process for Charlie at Waypoint A/B is judged to be **unsuccessful**. Their digital minimum standard assessment is overdue and they are the only supplier in my study group (plus the whole population of suppliers with a technology scorecard) where this is the case. However, on a more positive note, the actions in their Technology Engagement Plan (2019Q4) are satisfactory.
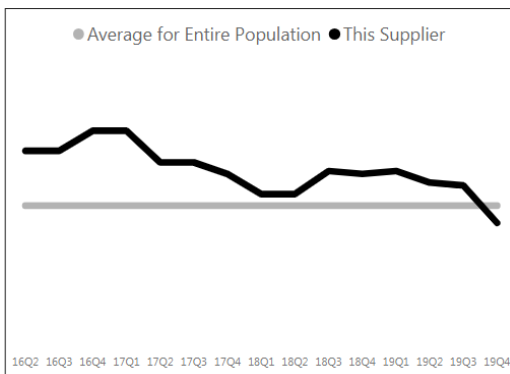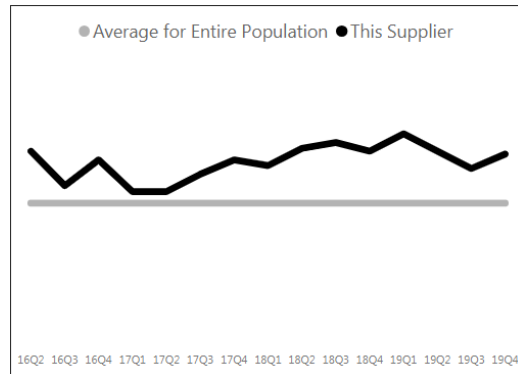
Supplier Scorecard (Technology)   **Supplier Scorecard (Operational)**

Delta

The relative absorptive capacity of Delta at 2019Q4 is categorised as **AC2**. Although consistently performing strongly, their technology score has remained flat since joining the SD/DT programme.

The outcome of the SD/DT process for Delta at Waypoint A/B is judged to be **successful**. They achieved the digital minimum standard by the end of 2019. Allowing for some mitigation because they achieved the digital minimum standard, the actions in their Technology Engagement Plan (2019Q4) are borderline satisfactory.

Supplier Scorecard (Technology)   **Supplier Scorecard (Operational)**

Paul Hacker, PhD thesis, University of Cambridge, May 2020
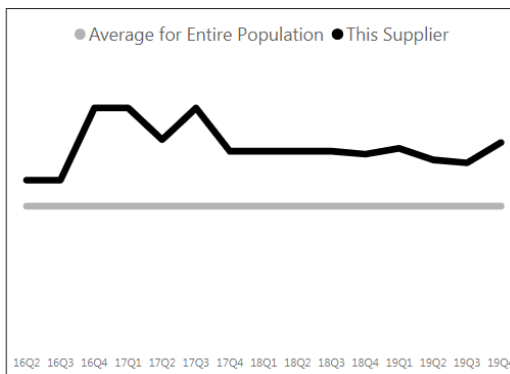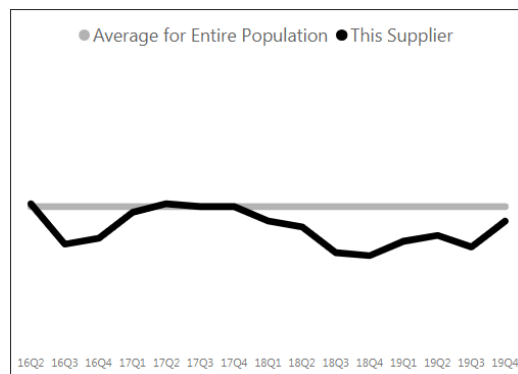
Echo

The relative absorptive capacity of Echo at 2019Q4 is categorised as **AC1**. They are a special case, because they are a new supplier to Rolls-Royce despite being highly competent and well established in the aerospace sector and beyond. They do not yet have a supplier scorecard (operational) and have only recently started using a supplier scorecard (technology). Therefore, the assessment of their absorptive capacity is based upon this together with an interview with their buyer at Rolls-Royce.

The outcome of the SD/DT process for Echo at Waypoint A/B was judged to be **successful**. They did not achieve the digital minimum standard by the end of 2019, but there is a gap closure plan for 2020 (albeit sparse).
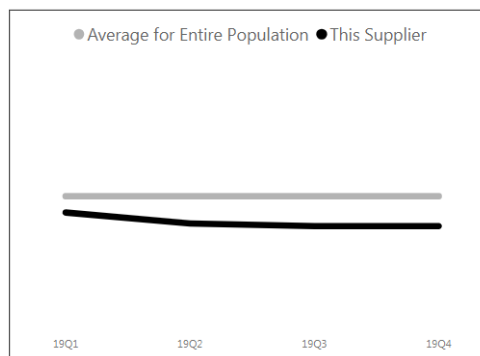
Supplier Scorecard (Technology)

Foxtrot

The relative absorptive capacity of Foxtrot at 2019Q4 is categorised as **AC4**. Their technology score has remained below average despite them being long term members of the SD/DT programme.

The outcome of the SD/DT process for Foxtrot at Waypoint A/B is judged to be **successful**. Although they did not achieve the digital minimum standard by the end of 2019, their gap closure plan for 2020 is reasonable. In addition, the actions in their Technology Engagement Plan (2019Q4) are satisfactory.
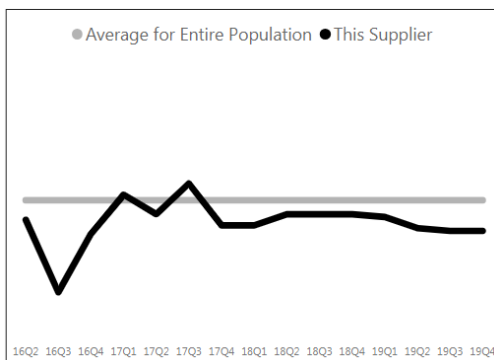
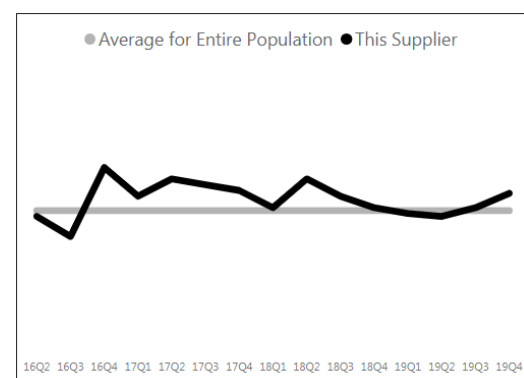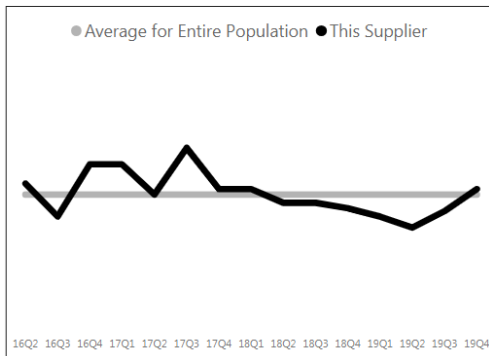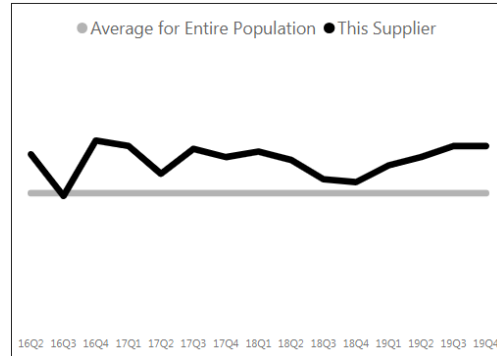**Supplier Scorecard (Technology)**
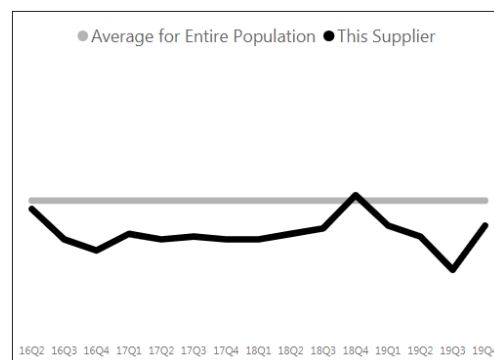
Supplier Scorecard (Operational)

Golf

The relative absorptive capacity of Golf at 2019Q4 is categorised as **AC1**. Although consistently performing strongly, their technology score has remained flat since joining the SD/DT programme.

The outcome of the SD/DT process for Golf at Waypoint A/B is judged to be **successful**. They did not achieve the digital minimum standard by the end of 2019; but exceeded most aspects and, where not, have a gap closure plan for 2020 (albeit sparse). In addition the actions in their Technology Engagement Plan (2019Q4) were satisfactory.
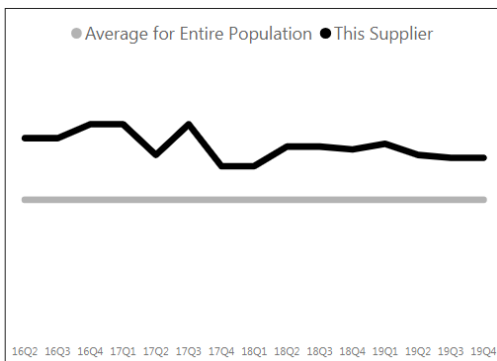
Supplier Scorecard (Technology)
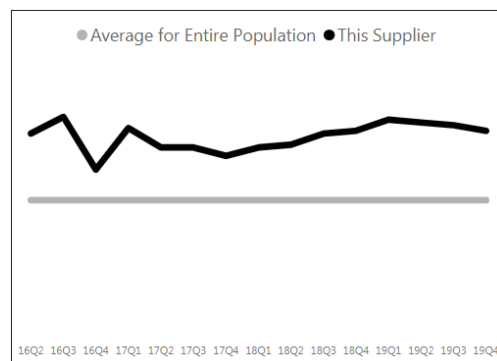
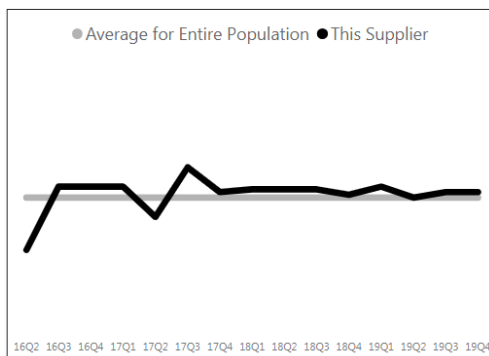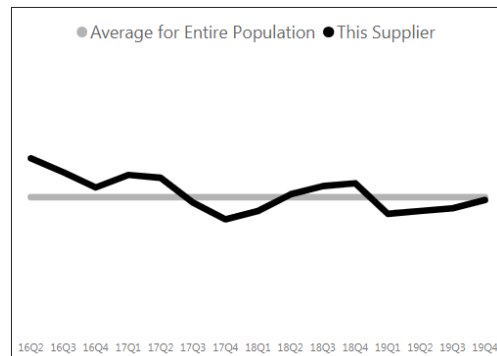**Supplier Scorecard (Operational)**

Hotel

The relative absorptive capacity of Hotel at 2019Q4 is categorised as **AC1**. They are a special case, because they are new to the SD/DT programme and are a large supplier with multiple sites. The scorecard results given below are a collated average across sites which masks this. Therefore, the assessment of their absorptive capacity is based upon an interview with their buyer at Rolls-Royce.

The outcome of the SD/DT process for Hotel at Waypoint A/B is judged to be **successful**. None of their sites achieve the digital minimum standard by the end of 2019, but some have gap closure plans for 2020. The actions across all sites in their Technology Engagement Plans (2019Q4) are satisfactory.

Supplier Scorecard (Technology)

Supplier Scorecard (Operational)

Paul Hacker, PhD thesis, University of Cambridge, May 2020

Indigo

The relative absorptive capacity of Indigo at 2019Q4 is categorised as **AC3–**. They are a long term member of the SD/DT programme; but, have a downward trend in their technology score.

The outcome of the SD/DT process for Indigo at Waypoint A/B is judged to be **successful**. Although they did not achieve the digital minimum standard by the end of 2019, their feedback on it's applicability to their circumstance is highly constructive and they include elements of a gap closure plan for 2020. The actions in their Technology Engagement Plan (2019Q4) are satisfactory.

Supplier Scorecard (Technology)	Supplier Scorecard (Operational)

Juliet

The relative absorptive capacity of Juliet at 2019Q4 is categorised as **AC3–**. They are a long term member of the SD/DT programme; but, have a downward trend in their technology score.

The outcome of the SD/DT process for Juliet at Waypoint A/B is judged to be **successful**. They achieved many aspects of the digital minimum standard by the end of 2019 and also have a continuous improvement plan for 2020. The actions in their Technology Engagement Plan (2019Q4) are satisfactory.

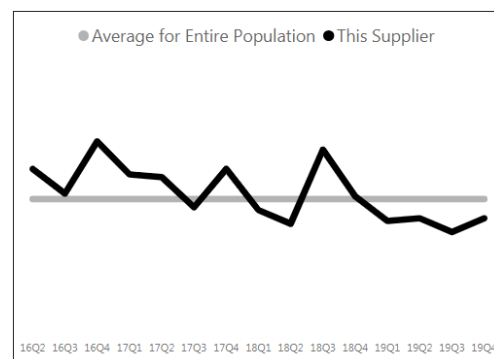| Supplier Scorecard (Technology)	Supplier Scorecard (Operational)

Kilo

The relative absorptive capacity of Kilo at 2019Q4 is categorised as **AC1**. They are a long term member of the SD/DT programme. Their technology score dipped, but has been on a sustained improvement trend over recent quarters. They have now returned to a similar position to when they started and therefore, overall, I have not attributed a positive or negative trend to their absorptive capacity.

The outcome of the SD/DT process for Kilo at Waypoint A/B is judged to be **successful**. Although they did not achieve the digital minimum standard by the end of 2019, their gap closure plan for 2020 is reasonable. The actions in their Technology Engagement Plan (2019Q4) are satisfactory.

Supplier Scorecard (Technology)   **Supplier Scorecard (Operational)**

Lima

The relative absorptive capacity of Lima at 2019Q4 is categorised as **AC1**. They are a long term member of the SD/DT programme and their technology score has remained flat and at the average.

The outcome of the SD/DT process for Lima at Waypoint A/B is judged to be **successful**. They have multiple sites with multiple scorecards; therefore, the results below are their collated average. One of their facilities achieved the digital minimum standard by the end of 2019 and also has a continuous improvement plan for 2020. In general, the actions in their TEP's (2019Q4) are satisfactory.

Supplier Scorecard (Technology)   **Supplier Scorecard (Operational)**

Paul Hacker, PhD thesis, University of Cambridge, May 2020

Oskar

The relative absorptive capacity of Oskar at 2019Q4 is categorised as AC2–. Although their technology score remains above average it has been on a downward trend, despite them being a comparatively long term member of the SD/DT programme..

The outcome of the SD/DT process for Oskar at Waypoint A/B is judged to be unsuccessful. This is driven by the other aspects of the assessment criteria (see Figure 4.7). Despite not achieving the digital minimum standards by the end of 2019, their gap closure plan and TEP actions are satisfactory.
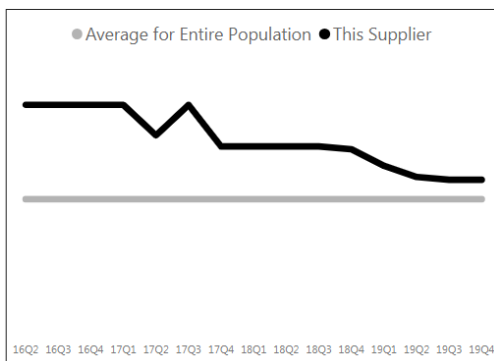
Supplier Scorecard (Technology)
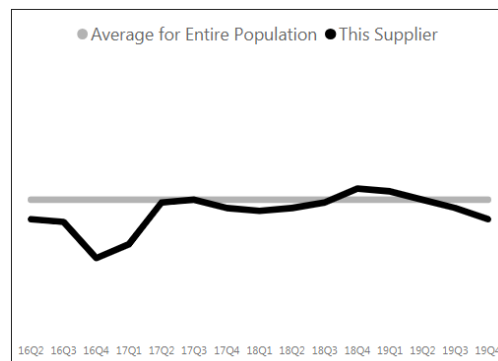
Supplier Scorecard (Operational)

Papa

The relative absorptive capacity of Papa at 2019Q4 is categorised as AC4. They are a medium term member of the SD/DT programme. The decision is taken to remove their supplier scorecard (tech) for 2020 and, therefore, AC is judged to be unsatisfactory. This was agreed with RR buyer. To maintain goodwill, their closing (2019Q4) techn score was more generous than it may have otherwise been.

The outcome of the SD/DT process for Papa at Waypoint A/B is judged to be unsuccessful. This is driven by other aspects of the assessment criteria (see Figure 4.7). Despite not achieving the digital minimum standards by the end of 2019, their gap closure plan and TEP actions are satisfactory.
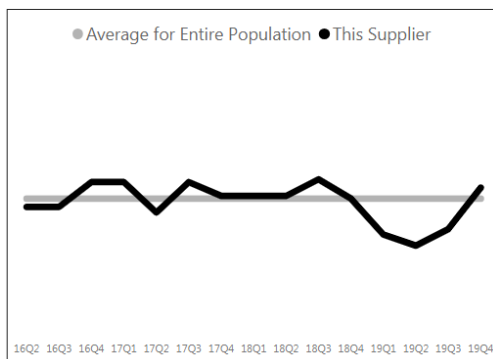
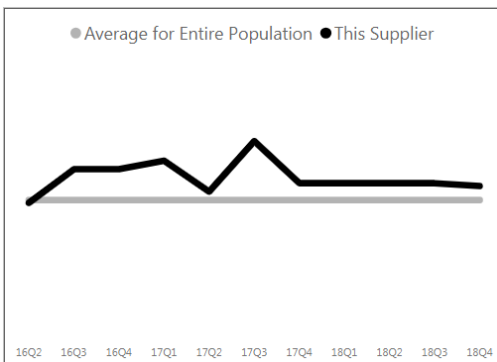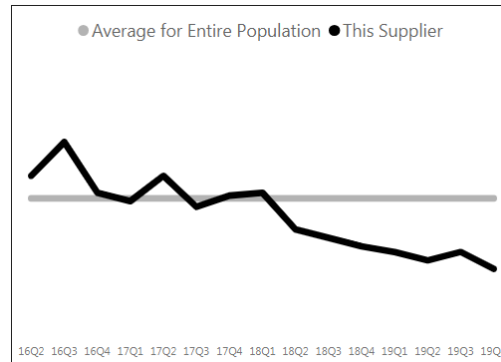**Supplier Scorecard (Technology)**

Supplier Scorecard (Operational)

Quebec

The relative absorptive capacity of Quebec at 2019Q4 is categorised as AC1#. Their supplier scorecard (technology) only ran up to the end of 2018; however, they continued to demonstrate positive behaviours which their buyer in Rolls-Royce used to justify a satisfactory level of absoptive capacity.

The outcome of the SD/DT process for Quebec at Waypoint A/B is judged to be successful. Since they do not have a supplier scorecard (technology) for 2019Q4, there is no data from it to support this particular aspect in the assessment of their outcome from the SD/DT programme.
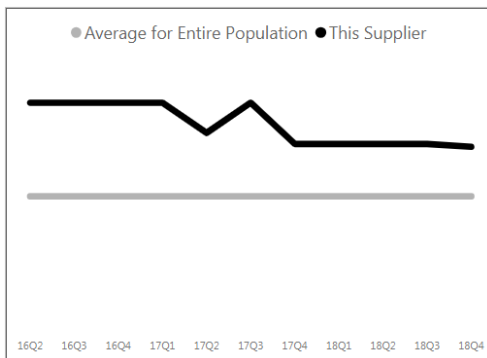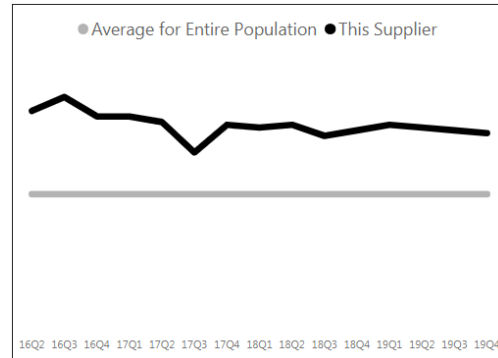
Supplier Scorecard (Technology) up to 2019   **Supplier Scorecard (Operational)**

Romeo

The relative absorptive capacity of Romeo at 2019Q4 is categorised as AC4#. Their supplier scorecard (technology) only ran up to the end of 2018; however, around this time, the strategic nature of the relationship deterioriated and working together on technology stopped. Therefore, the relative absoptive capacity has been assessed at being unsatisfactory since.

The outcome of the SD/DT process for Romeo at Waypoint A/B is judged to be unsuccessful. Since they do not have a supplier scorecard (technology) for 2019Q4, there is no data from it to support this particular aspect in the assessment of their outcome from the SD/DT programme.

Supplier Scorecard (Technology) up to 2019   **Supplier Scorecard (Operational)**

**Paul Hacker, PhD thesis, University of Cambridge, May 2020**

Sierra

The relative absorptive capacity of Sierra at 2019Q4 is categorised as AC1#. They are a newly formed multi-national who are new to the SD/DT programme. One of their sites had a supplier scorecard (technology) up to the end of 2018 as shown below. For 2020, it is planned that the multi-national will have one; therefore, the relative absorptive capacity has been assessed as being satisfactory.

The outcome of the SD/DT process for Sierra at Waypoint A/B is judged to be successful. Since they do not have a supplier scorecard (technology) for 2019Q4, there is no data from it to support this particular aspect in the assessment of their outcome from the SD/DT programme.
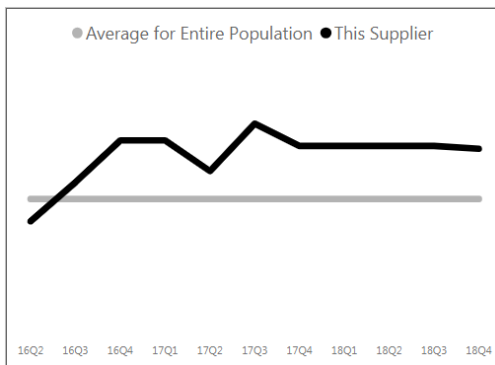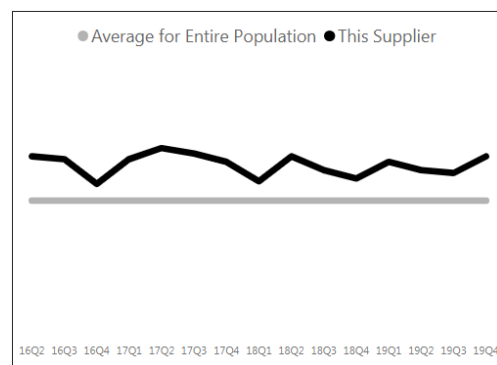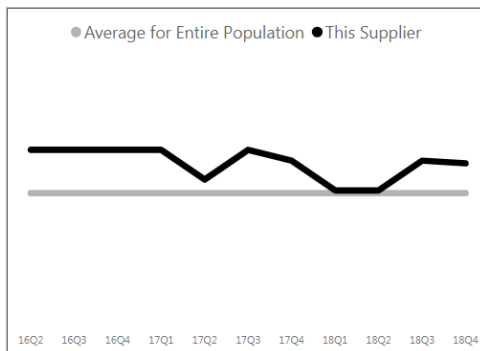

Supplier Scorecard (Technology) up to 2019   **Supplier Scorecard (Operational)**

Tango

The relative absorptive capacity of Tango at 2019Q4 is categorised as AC4#. Their supplier scorecard (technology) only ran up to the end of 2018. However, their relative absoptive capacity is based upon it being stopped and their historical performance. This was agreed with their buyer in Rolls-Royce.

The outcome of the SD/DT process for Romeo at Waypoint A/B is judged to be unsuccessful. Since they do not have a supplier scorecard (technology) for 2019Q4, there is no data from it to support this particular aspect in the assessment of their outcome from the SD/DT programme.
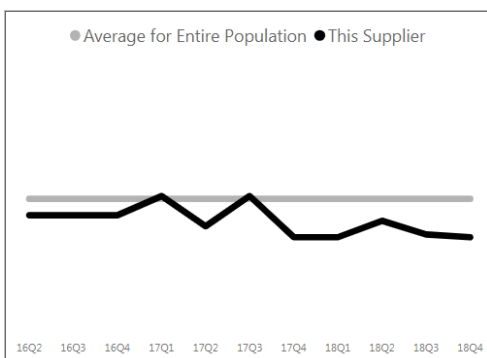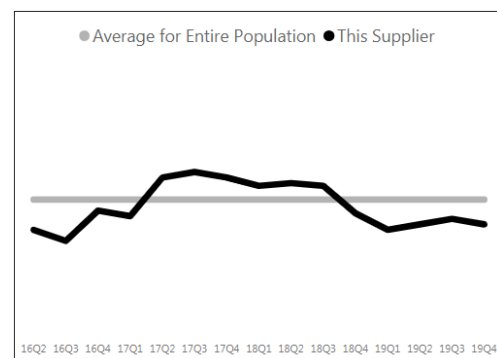
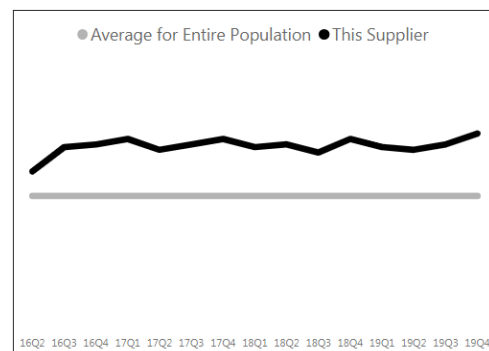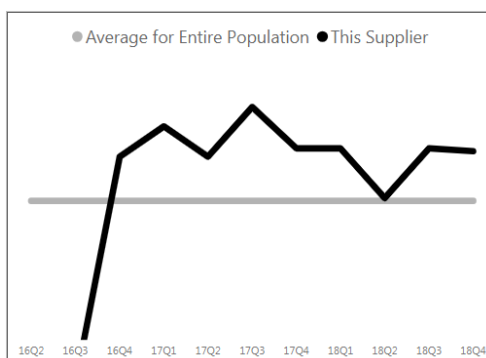**Supplier Scorecard (Technology) up to 2019**   **Supplier Scorecard (Operational)**

Uniform

The relative absorptive capacity of Uniform at 2019Q4 is categorised as AC1#. Their supplier scorecard (tech) only ran up to the end of 2018; however, they continued to demonstrate positive behaviours which their buyer in Rolls-Royce used to justify a satisfactory level of absoptive capacity.

The outcome of the SD/DT process for Uniform at Waypoint A/B is judged to be successful. Since they do not have a supplier scorecard (technology) for 2019Q4, there is no data from it to support this particular aspect in the assessment of their outcome from the SD/DT programme.

Supplier Scorecard (Technology) up to 2019   **Supplier Scorecard (Operational)**
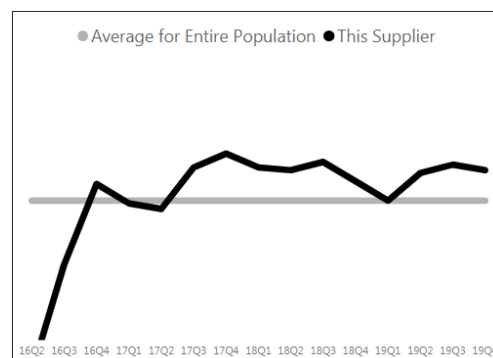
Victor

The relative absorptive capacity of Victor at 2019Q4 is categorised as AC1#. Their supplier scorecard (technology) only ran up to the end of 2018; however, they continued to demonstrate positive behaviours which their buyer in Rolls-Royce used to justify a satisfactory level of absoptive capacity.

The outcome of the SD/DT process for Victor at Waypoint A/B is judged to be successful. Since they do not have a supplier scorecard (technology) for 2019Q4, there is no data from it to support this particular aspect in the assessment of their outcome from the SD/DT programme.
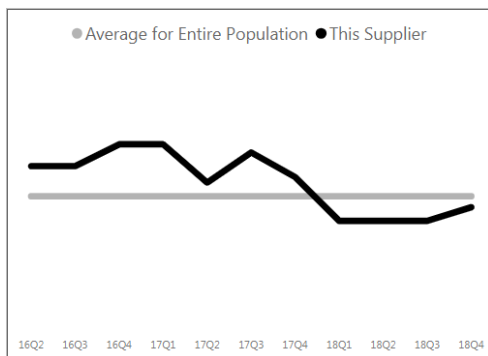

Supplier Scorecard (Technology) up to 2019   **Supplier Scorecard (Operational)**

Paul Hacker, PhD thesis, University of Cambridge, May 2020

Whiskey

The relative absorptive capacity of Whiskey at 2019Q4 is categorised as **AC3#**. Their supplier scorecard (tech) only ran up to the end of 2018. However, their relative absoptive capacity is based upon it being stopped and their historical performance. This was agreed with the Rolls-Royce buyer.

The outcome of the SD/DT process for Whiskey at Waypoint A/B is judged to be **unsuccessful**. Since they do not have a supplier scorecard (technology) for 2019Q4, there is no data from it to support this particular aspect in the assessment of their outcome from the SD/DT programme.
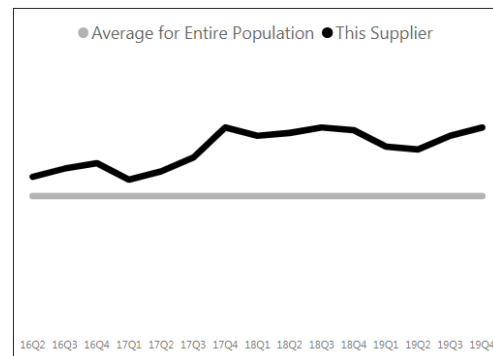
Supplier Scorecard (Technology) up to 2019   **Supplier Scorecard (Operational)**

X-ray

The relative absorptive capacity of X-ray at 2019Q4 is categorised as **AC1#**. They do not have a supplier scorecard (technology) nor (operational); therefore, an assessment of their absoptive capacity was made in conjunction with their buyer at Rolls-Royce. Also, using the criteria in Figure 4.7, the outcome of the SD/DT process for X-ray at Waypoint A/B is judged to be **successful**.

Yankee

The relative absorptive capacity of Yankee at 2019Q4 is categorised as **AC1#**. They do not have a supplier scorecard (technology) nor (operational); therefore, an assessment of their absoptive capacity was made in conjunction with their buyer at Rolls-Royce. Also, using the criteria in Figure 4.7, the outcome of the SD/DT process for Yankee at Waypoint A/B is judged to be **successful**.

Zulu

The relative absorptive capacity of Zulu at 2019Q4 is categorised as **AC1#**. They do not have a supplier scorecard (technology) nor (operational); therefore, an assessment of their absoptive capacity was made in conjunction with their buyer at Rolls-Royce. Also, using the criteria in Figure 4.7, the outcome of the SD/DT process for Zulu at Waypoint A/B is judged to be **successful**.

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