

**Deliberate Development of Asset Frontiers  
in Innovative Manufacturing Businesses**

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## Abstract

Manufacturing companies need to be innovative to ensure long term success. This requires organisations to reconcile the conflicting temporal demands of a dynamic business environment and the more gradual development of infrastructure, systems and people. This challenge is explored by examining the relationship between a firm's innovation propensity and the profile of its portfolio of manufacturing resources.

The Theory of Performance Frontiers [1] is used to characterise the capability profile arising from a firm's suite of assets and resources. The theory contends that the distance between a firm's *operating frontier* (OF) and its *asset frontier* (AF) is related to the manufacturing unit's ability to be agile and flexible. A new measure is developed and validated that represents the gap between the frontiers – the OF-AF Gap.

The organisation's innovation propensity is shown to have a *negative* impact on firm performance unless it is accompanied by a correspondingly large OF-AF gap. It is therefore important that the gap is actively managed by addressing its three constituent elements.

Firstly, organisational learning should be planned along the technological trajectory of the business *ahead* of current needs. Secondly, product development resources should be balanced between exploitative and explorative projects, with exploration grounded in the fertile areas created by prior knowledge-acquisition activities. Thirdly, justification for investment in physical assets should not be limited to project-related benefits, but should incorporate the capability-building value new equipment brings to the organisation. The acquisition of equipment that has capability beyond immediate project-specific requirements then becomes more justifiable in a financial environment where return-on-investment is king.

The research concludes by developing a simple tool that allows an organisation's OF-AF gap to be enumerated on a normalised scale. This unlocks the potential for firms to benchmark themselves against industry norms and to numerically incorporate the capability-building value of asset investments in financial justifications.

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## Author's Declaration

I declare that this thesis is a presentation of original work and I am the sole author. This work has not been presented for an award at this, or any other, University. All sources are acknowledged as references.

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# Chapter 1: Introduction

I have worked in a product development role in manufacturing organisations for my 35 year career to date and this provides the personal context of this research. I have a keen interest in understanding how product innovation can be applied in a manufacturing environment. My experience has led me to question how the often dynamic nature of innovation can be effectively applied in a production context where infrastructure, systems and people take significant time to source, develop and become effective.

Many authors observe the need for innovation to facilitate and power an organisation's growth. For example, Braganza et al [2] state that the *'ability of an organisation to innovate is paramount'* and Buisson & Silberzahn [3] contend that innovation is *'widely recognised as a major driver of long-term corporate growth'*. Tidd & Bessant [4, p xv] go further and state that *'innovative firms grow twice as fast, both in employment and sales'*.

Goffin & Mitchell [5, p2] identify four areas – technological advances, changing customer needs, intensified competition and changing business environment – that drive the need for innovation in organisations striving to maintain competitive advantage that will underpin long term profitability. Cooper [6, p15] contends that a direct consequence of two of these – technological advances and changing customer needs – is the shortening of product life-cycles, which challenges both the innovation capability of the organisation not only in product design but also in bringing such products to fruition via its manufacturing operations.

*"Innovative products are critical to your long-term success. They keep your business's product portfolio competitive and healthy, and in many firms, provide you with long-term and sustainable competitive advantage."* [6, p17]

To understand how a firm's innovative ambition can be effectively realised in a manufacturing organisation it is necessary to consider two distinct areas of literature. The first area relates to the development of an innovation strategy which responds to the competitive and technological environment and encompasses the wider strategic management of the business. The second area is concerned with the mechanisms that drive the evolution of production resources including physical assets, systems



infrastructure and human capabilities. This literature area includes manufacturing strategy and the resource-based view of the firm.

The innovation and strategic management literature review in section 2.2 will show that the laudable aspiration for an innovative and dynamic product portfolio is compromised by many practical considerations. A firm’s carefully thought-through strategy is often challenged by events, whether that is new technology, disruptive innovations by competitors, or new regulations. There is a need to respond quickly and effectively to emerging new information. An organisation’s rational and deliberate strategic planning is usually accompanied by incremental or ‘emergent’ adjustments as new information comes to light.

Manufacturing strategy literature and the resource-based view of the firm are reviewed in section 2.3. This review confirms that in manufacturing businesses, production resources change relatively slowly. The firm’s technological history and current position are often idiosyncratic, have significant inertia and limit available options for the future.

It will be shown that manufacturing strategy is typically driven by the overarching business strategy, and is therefore often reactive in nature. Manufacturing strategy is focused on developing competitive capabilities that achieve and maintain alignment with the business strategy. The strategic and timely development of resources in support of a firm’s innovation intent is often a secondary consideration at best.

The conclusion drawn in section 2.4 is that these two areas of literature are both fundamental to a manufacturing business’ performance but that they are typically not considered together. Table 1 captures some of the contrasting characteristics emerging from the literature review that must be reconciled for manufacturing businesses to be successful.

<b>Innovation &amp; Strategic Management Literature</b>	<b>Manufacturing &amp; Resource-Based View Literature</b>
A dynamic environment: <ul style="list-style-type: none"> <li>• Rate of technology development</li> <li>• Disruptive innovation</li> <li>• Global competition</li> <li>• Shortened product life cycles</li> </ul>	Generally slow-moving resources: <ul style="list-style-type: none"> <li>• Asset acquisition &amp; deployment</li> <li>• Skills development &amp; efficacy</li> <li>• Production systems adaptability</li> <li>• Resource reconfiguration</li> </ul>

**Table 1 – Contrasting Innovation & Manufacturing Characteristics**

The literature review concludes with the observation that the interface between these bodies of literature occurs at the point where the product portfolio plan arising from the firm's innovation strategy starts to drive changes in the assets and resources in the operations unit. It will be shown that the ability of the operations unit to respond in a timely manner to the requirements of the product portfolio plan depends on the profile and characteristics of existing assets and resources.

This research uses the Theory of Performance Frontiers (Schmenner & Swink [1] and Vastag [7]) to characterise the capability and performance profile arising from a firm's unique suite of assets and resources. The theory, which is reviewed in detail in section 2.3, describes two performance frontiers – an *asset frontier* created by investments in physical equipment, plant and technology, and an *operating frontier* set by the policies and procedures put in place by the operations management team given the suite of assets at their disposal. The Theory of Performance Frontiers contends that the relative position of the two frontiers (i.e. the distance between them) is related to the manufacturing unit's ability to be agile and flexible.

In order to investigate how manufacturing units can respond with agility to the innovation demands of the wider organisation, this research develops a measure for the distance between the operating and asset frontiers. The development of this new measure necessarily affects the structure of this thesis.

This thesis is organised as follows:

The next chapter, chapter 2, reviews the two pertinent areas of literature – innovation & strategic management, and the resource-based view of the firm & manufacturing strategy. The focus of this research, the process of developing innovation strategies and realising them in the manufacturing arena, is found at the boundary between these two literature topics.

In chapter 3 a series of hypotheses are developed that seek to explain the relationship between the way innovation strategy is developed in businesses and the consequential impact on the resources and suite of assets that combine to create the competitive potential of the manufacturing unit. In order to test these hypotheses the first research objective is established which is to create a new metric to the literature which measures the distance between firms' operating and asset frontiers.

The nature of research philosophy and how it applies to this work is considered in chapter 4. Different research methodology models are compared and one is then selected to guide the development of the methodology for this research. A quantitative

survey instrument is selected as the primary research tool – a questionnaire which captures data relating to the hypothesis variables as well as the proposed constituent variables of the new performance frontier metric. Critical criteria are established from the literature against which to judge whether a reliable and valid new metric has, in fact, been created.

Chapter 5 describes the development of the research questionnaire. Question sets are selected from peer-reviewed literature for each of the hypothesis variables and the constituent variables of the new metric. Demographic questions are also incorporated.

The piloting of the research questionnaire with multiple respondents from a single organisation is presented in chapter 6. The pilot enables the consistency of response to be evaluated from a variety of respondents from different businesses functions and different seniority levels. The subsequent analysis resulted in minor modifications to the questionnaire to be used in the main survey, and clarified the optimum respondent profile.

Chapter 7 describes the deployment of the main survey. The survey response is discussed and the frequency profiles of responses to demographic questions is presented. Finally, the numeric manipulation of the data that is required for the statistical analysis is described.

The statistical analysis of the main survey responses is presented in chapter 8. Initial checks for data normality and reliability are reviewed. An assessment is made to establish whether the analysis results satisfy the critical criteria set out in chapter 4 for the successful creation of a reliable and valid new metric, and the series of hypotheses proposed in chapter 3 are then tested.

Chapter 9 discusses the results arising from the statistical analysis of chapter 8. Firstly, the factor profile of the new metric that measures the distance between firms' operating and asset frontiers is reviewed and assessed for consistency with the literature. The results of the hypothesis testing are then considered, followed by a review of the statistical effect sizes arising from the analysis and the consequent generalisability of the results to the wider manufacturing population.

In order that the new metric developed in this research is easily accessible and enumerated for future researchers, a simple calculation method is developed in chapter 10. The behaviour of this spreadsheet-generated scale is compared with the output of the exploratory factor analysis from the main analysis in chapter 8 to ensure

consistency. Selected statistical means are then calculated using this new tool for the distance between firms' operating and asset frontiers for different demographic splits.

Chapter 11 presents the conclusions from the research and the consequent implications for management teams in manufacturing businesses are developed. This is followed by a summary of the academic contribution and practical impact of the work.

Finally, in chapter 12 several limitations of this research are discussed. Areas of further research are then proposed to address these limitations followed by suggestions for additional research to enhance management practice.

## Chapter 2: Literature Review

### 2.1 Introduction

The focus of this research is the development and application of innovation in a manufacturing environment. Innovation management and the issues surrounding a firm's ability to respond to the external environment are largely addressed in the strategic management literature. Capabilities and resources required to operationalise innovative intent are the domain of the manufacturing strategy and operations management literature.

It is intuitively reasonable that there should be an alignment and a parity of importance attached to these two bodies of literature. However, it is clear that they are, in fact, relatively separate with little interlinkage. Brown & Blackmon [8, p794] contend that *'manufacturing has increasingly lost touch with mainstream corporate and business strategy literature'*. González-Benito & Suárez-González [9] observe that in spite of efforts to redress the balance, manufacturing's role remains subservient and reactive to corporate strategy.

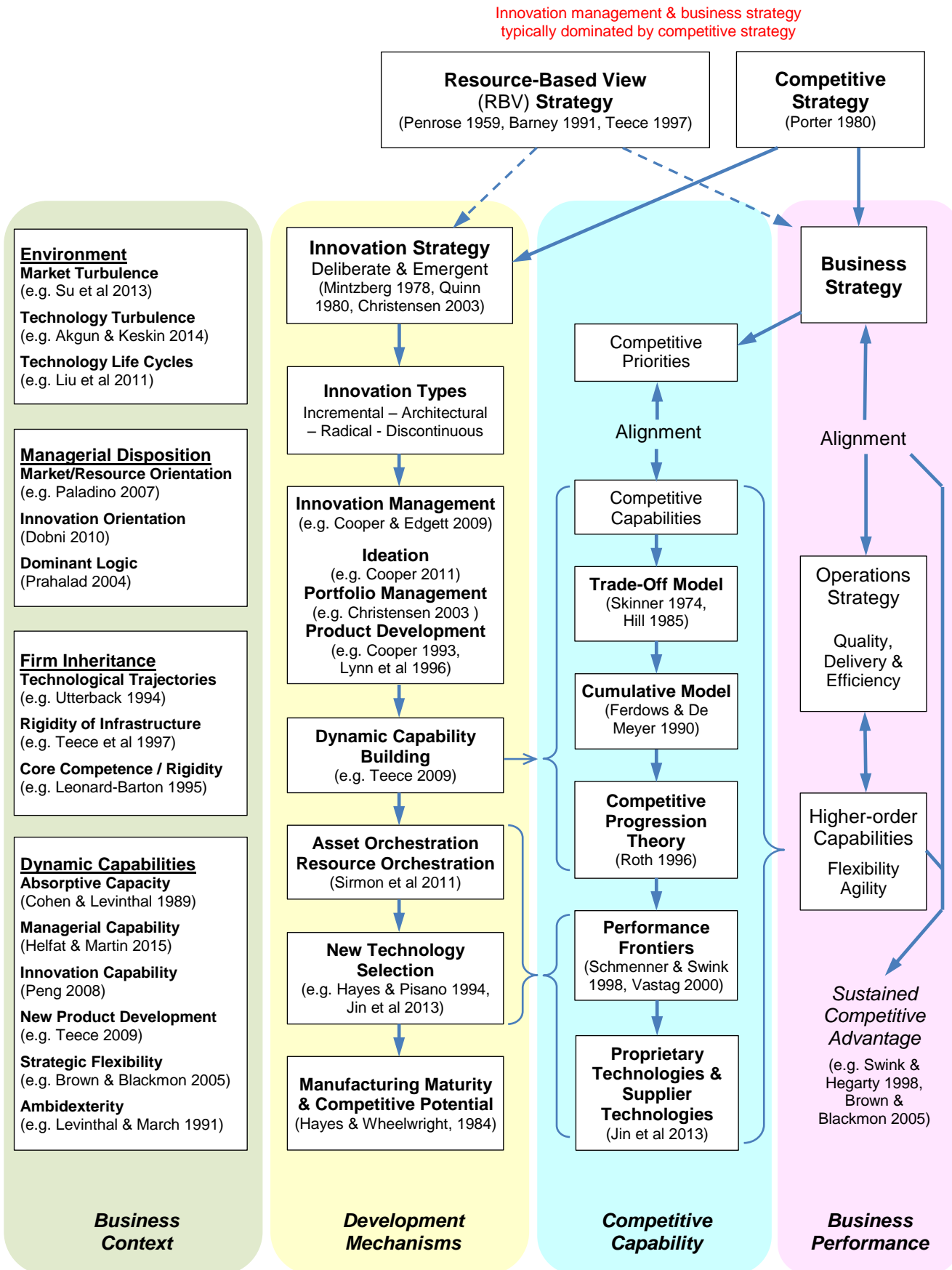
More recently Maritan & Lee [10, p2412] find it 'surprising' that given the importance of resource allocation to strategic management there is not more research that explores this relationship.

Given the relatively distinct nature of the two areas of interest, the literature review that follows is organised accordingly. Section 2.2 reviews the innovation and strategic management literature while section 2.3 looks at resource-based strategy and manufacturing strategy.

The definition of innovation is initially discussed in section 2.2 followed by a review of its dynamic nature and how it is affected by external stimuli. The management of innovation is examined before considering the issues surrounding the innovative posture of the firm. Finally in this section the overarching role of strategic management and the complementary processes of deliberate and 'emergent' strategy development are reviewed.

Section 2.3 looks at the development of the resource-based view of the firm and how this contrasts with Porter's competitive strategy which has historically dominated the strategic management literature. The development of resources and knowledge in the

Figure 1 – Literature Map



manufacturing environment is then considered through the lenses of dynamic capabilities and absorptive capacity. The evolution of manufacturing strategy is presented and competing theories of how manufacturing units develop key capabilities are discussed.

Section 2.4 draws together the themes from the previous two sections and identifies the key area for research focus.

Figure 1, opposite, graphically represents the literature landscape of this research. The diagram organises the elements of literature reviewed in this chapter into four columns from left to right:

1. The business context within which corporate, operations and innovation strategies are developed, set and implemented.
2. Development mechanisms that effect changes to products, technologies and capabilities.
3. The competitive capability of the organisation at a point in time
4. Business performance, where sustained competitive advantage arises from an alignment between business strategy and operations strategy, coupled with the higher-order competitive capabilities of flexibility and agility.

The diagram also indicates the dominance of Porter's competitive strategy on both business strategy and innovation strategy at the expense of the resource-based view.

## 2.2 Innovation & Strategic Management

### 2.2.1 Innovation Categorisation

Tidd & Bessant [4, p39] contend that innovation is more than just creativity, original thought or inventiveness – it relies on the *exploitation* of ideas.

*“Innovation is about knowledge – creating new possibilities through combining different knowledge sets.”* [4, p39]

In examining the exploitation of knowledge set combinations in organisations, innovation has been considered by academics and practitioners across numerous

dimensions, and in doing so different typologies and categories of innovation have been created, often with inconsistent labels.

For example:

- Henderson & Clark [11] consider a systems approach where the degree of change to core concepts is mapped against the degree of change to the linkages between core concepts and components. This leads to category labels 'radical', 'architectural', 'modular' and 'incremental' innovation.
- Christensen [12, 13] distinguishes between 'sustaining' and 'disruptive' innovation, where sustaining innovation perpetuates the status quo in terms of the market leadership of incumbent organisations, and disruptive innovations allow new entrants to undermine the incumbents' position by introducing perhaps 'less good' products, processes or business models that are simpler and more cost effective.
- Abernathy & Clark (as cited in Ellonen et al [14]) and Markides & Geroski [15] consider the degree of effect of innovation on customers and the market mapped against the degree of effect of innovation on technology and competences. This leads to category labels 'architectural', 'revolutionary', 'niche' and 'regular' innovation in Abernathy & Clark, and 'radical', 'strategic', 'major' and 'incremental' innovation in Markides & Geroski.
- O'Connor [16] introduces the term 'major innovation' which incorporates innovation that induces market and technical discontinuities at both firm and industry levels.
- Kaafarani & Stevenson [17] propose a hierarchical typology – 'transformational', 'category', 'marketplace' and 'operational' innovation – contending that innovations can and do cascade from higher levels to lower levels as the innovation's value is exploited over time.

British Standards' *Guide to Managing Innovation* [18] suggests that innovation's 'degree of newness' can be considered as a continuum with 'new to an individual' at one extreme and 'new to the world' at the other.

Building on this approach, the numerous innovation categories and typologies found in the literature have been positioned in table 2 along an approximate continuum from incremental innovation at one end to transformational innovation at the other.



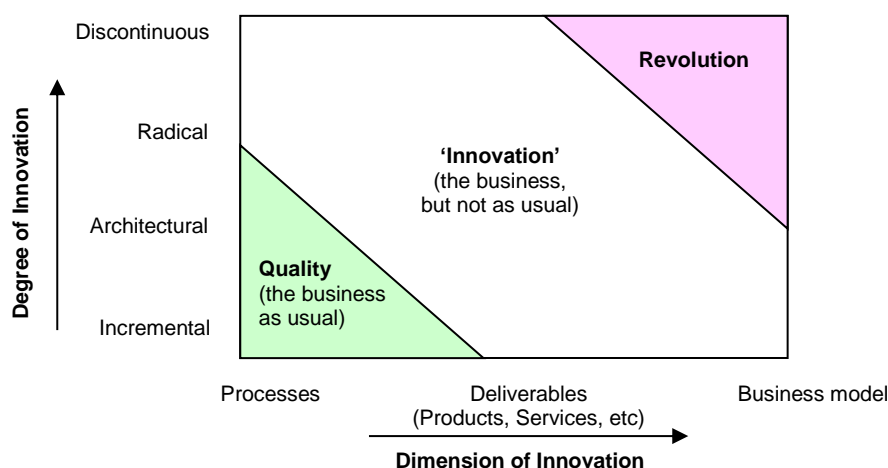
**Table 2 - Innovation Categorisation**

Transformational	"It comes along rarely ... it's a disruptive breakthrough that changes society and so impacts the way people live that they can't thrive without it." [17, p46]
Disruptive	"... products and services that are not as good as currently available products ... [but] offer other benefits – typically, they are simpler, more convenient, and less expensive products that appeal to new or less-demanding customers." [13, p34] "Innovation with a significant adverse effect within and/or outside an organisation that cannot be influenced or controlled in the short term." [18, p8]
Breakthrough	"Change that breaches a previously perceived limit in configuration, performance or technology." [18, p8] "... that which generally breaks paradigms, is based on new product designs, and is generally incompatible with existing dominant products." [19, p67]
Discontinuous	"... radical advances that may profoundly alter the basis for competition in an industry" [20, p77]
Strategic	"...based on new business designs." [15, p6] "[Major innovations] comprising the radical and really new innovations ... with the meaning of strategically and continuously creating new products, services, and business models..." [21, p77]
Major	"...require fundamental changes in consumer behaviour but build upon the established players' competences and complementary assets." [15, p5] "...composed of both radical and really new innovation." [16, p313]
Radical	"...establishes a new dominant design and, hence, a new set of core design concepts embodied in components that are linked together in a new architecture." [11, p11] "... they introduce major new value propositions that disrupt existing consumer habits and behaviours ... [and] the markets that they create undermine the competences and complementary assets on which existing competitors have built their success." [15, p4] "Radical innovations transform existing markets or industries or create new ones" [16, p315] "innovation resulting in significant (sometimes step) changes that could not have been extrapolated from present state." [18, p12]
'Really New'	"...exhibits macro level discontinuity on either the market or technical dimension..." [16, p315]
Modular	"...changes only the core design concepts of a technology" – i.e. not the architecture of the components [11, p12]
Architectural	"... is the reconfiguration of an established system to link together existing components in a new way." [11, p12] "... technological or process advances to fundamentally change a component or element of the business." [20, p77] "... when radical technology is applied to new markets." [14, p754]
Revolutionary	New technology and production capabilities applied to existing markets [14, p754]
Category	"... often found in the new application of existing ideas, products, and services, or markets served, rather than in the creation of entirely new inventions." [17, p46]
Niche	"...opening up new market opportunities, but through the use of existing technology." [14, p754]
Marketplace	"... to bring new life to existing products through innovation. This most often means building or expanding into new markets ..." [17, p47]
Sustaining	"targets demanding, high-end customers with better performance". Some sustaining innovations are incrementally innovative and some are breakthrough." [13, p34]
Operational	"... more internally than externally focused ... In the simplest terms, operational innovation is about doing things faster, cheaper and better." [17, p47]
Regular	"... change that builds on established technical and production capabilities and is applied to existing markets and customers." [14, p754]
Incremental	"... refines and extends an established design." [11, p11] "... small improvements in existing products and operations" [20, p77] "... extend the current proposition facing consumers. They introduce relatively minor changes to the product or service..." [15, p5] "... relatively minor innovations that are predictable extrapolations from the present state." [18, p9] "... refinement of an established design in a way that yields price or performance improvements" [19, p67] "... version updates through small-scale improvement of existing products and services." [21, p77]

The continuum of innovation types shown in table 2 is a good, but not perfect, fit given the very specific meanings attached to the category labels by individual authors. For the purposes of this research, and for simplicity, these 18 terms will be grouped under four headings as follows:

- **Discontinuous Innovation** (covering ‘transformational’, ‘disruptive’, ‘breakthrough’ and ‘discontinuous’ innovation). Innovation that significantly changes the basis of competition in an industry.
- **Radical Innovation** (covering ‘strategic’, ‘major’, ‘radical’ and ‘really new’ innovation). Innovation that introduces a step change in product technology and market approach.
- **Architectural Innovation** (covering ‘modular’, ‘architectural’, ‘revolutionary’, ‘category’, ‘niche’ and ‘marketplace’ innovation). Innovation that applies new technology to existing markets, or opens up new markets using existing technology.
- **Incremental Innovation** (covering ‘sustaining’, ‘operational’, ‘regular’ and ‘incremental’ innovation). Innovation that creates small improvements in existing products or operations.

Goffin & Mitchell [5] combine both the degree of innovation and the extent to which it is applied in the business – the ‘dimension of innovation’. Their graphical representation has been adapted in figure 2 to include the four degrees of innovation described above. This shows the range of practical application of innovation from continuous improvement through to business transformation.



**Figure 2 – Continuous Improvement & Innovation**  
(adapted from Goffin & Mitchell [5, p16])

The bottom left-hand corner is where the organisation’s quality management system dominates as continuous, incremental improvements are made. The fundamental

nature of the organisation is not affected. The upper right-hand corner is where revolutionary change occurs affecting the business model of the organisation. The large central area is where robust innovation management must be employed.

The next section discusses the ability of an organisation to effectively exploit innovation, whether incremental or discontinuous, and how that ability is influenced by the events that have triggered the need for innovation and the position of the organisation in its business, technology and product life cycles.

## 2.2.2 Innovation Dynamics

Organisation processes and systems that have been designed to cater for a steady-state environment are often not equipped to deal with dynamic situations when innovation discontinuities are present [22]. Phillips et al [23] identify a range of situations that can trigger innovation discontinuities and the problems they pose for organisations and the management of their innovation. These are shown in table 3 and many of the problems cited are discussed in subsequent sections of this chapter.

**Table 3 - Triggers of Innovation Discontinuity**  
(Adapted from Phillips et al [23, pp178-9])

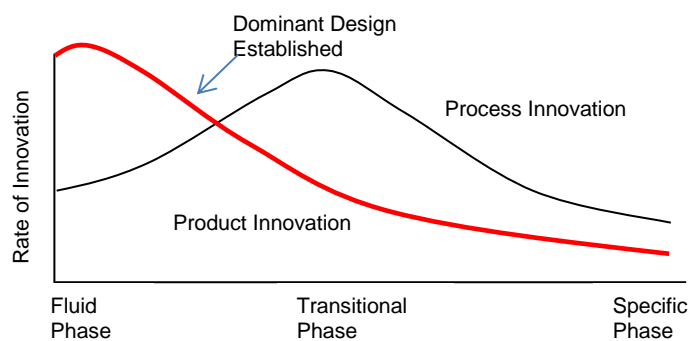
Trigger	Problems Posed
New market emerges	<ul style="list-style-type: none"> <li>Established players do not see it because they are focused on their existing markets.</li> <li>May discount it as being too small or not representing their preferred target market—fringe/cranks dismissal.</li> </ul>
New technology emerges	<ul style="list-style-type: none"> <li>Firms often do not see it because it is beyond the periphery of their technology search environment.</li> <li>Not an extension of current areas but completely new field or approach.</li> <li>Not invented here effect.</li> </ul>
New political rules emerge	<ul style="list-style-type: none"> <li>Old mindset about how business is done, rules of the game, etc., are challenged and established firms fail to understand or learn new rules.</li> </ul>
Running out of road	<ul style="list-style-type: none"> <li>Current system is built around a particular trajectory and embedded in a “steady-state” set of innovation routines which militate against widespread search or risk-taking experiments.</li> </ul>
Sea change in market sentiment or behaviour	<ul style="list-style-type: none"> <li>Firms do not pick up on it or persist in alternative explanations – cognitive dissonance – until it is too late.</li> </ul>
Deregulation/ shifts in regulatory regime	<ul style="list-style-type: none"> <li>New rules of the game but old mindsets persist and existing player unable to move fast enough or see new opportunities opened up.</li> </ul>
Fractures along “fault lines”	<ul style="list-style-type: none"> <li>Rules of the game suddenly shift and then new pattern gathers rapid momentum wrong-footing existing players working with old assumptions.</li> </ul>
Unthinkable events	<ul style="list-style-type: none"> <li>New rules may disempower existing players or render competencies unnecessary</li> </ul>

The point at which a technology is in its life cycle (its 'S' curve of emerging, growth, maturity & decline [5, p101]), will affect the type of innovation that is possible and indeed what is actually *required* to maintain competitiveness in response to discontinuity [5, p102]. All technologies have a limit to how far they can be developed and pushed. If this limit is reached incremental developments may no longer be effective and substantial innovation may then be required.

*“An organisation that relies on a capability that is approaching the top of its ‘S’ curve is vulnerable. It is therefore imperative to understand key capabilities well enough to be clear where their limits lie and what the alternatives might be.” [5, p102]*

The pace at which a mature, vulnerable technology might be replaced will depend both on how difficult it is to extend its capability – a process that will have diminishing returns – and the level of challenge associated with adopting the new technology [24].

Technology changes occur not only as organisations recognise the maturity of their existing capabilities but also as a consequence of external discontinuous events. The dynamic situation that results is shown in figure 3. The work of Tushman [25], Anderson [26], and Utterback [27] describe how the emphasis on product and process innovations evolves following significant changes in technology.



**Figure 3 - The Dynamics of Innovation**  
[27, pxvii]

Operating conditions in organisations are usually stable with activities focused on incremental product development activities. However, a technological, market or regulatory event can trigger the need for the firm to take steps to adapt to the change in ways it is not necessarily accustomed to.

*“Following a discontinuous event that disrupts the existing stability, there is a phase in which lots of companies rush to explore new options ... This*

*‘fluid’ phase is characterised by the co-existence of old and new technologies and by rapid improvements of both ... Eventually there is a ‘dominant design’ established – not always the best in purely technological terms, but one which becomes the innovation standard.” [22, p7]*

Once the dominant design has been established the focus switches from product innovation to process innovation in order to consolidate the dominant design. This is primarily concerned with improving processes to deliver optimum cost, quality, volume and branding [5, p104] [28, p92].

The dynamism involved in a business establishing a dominant design tends to ebb away as the design is established and optimised, leading to the conclusion that that business cannot be at the heart of the next cycle of fluid change – it is irreversible [27, p30]. Standards tend to be enforced, the pace of major innovation slows, the direction of innovation goes towards process, quality and cost. The dominant design creates boundaries for, and therefore constrains future innovation [27, p50].

A similar dynamic has been shown to apply by Henderson & Clark [11] when considering architectural and component innovation in products consisting of an assembly of several sub-systems. As a dominant design becomes established attention switches from architectural to component knowledge.

Technologies to be considered for adoption during the fluid phase can be driven by market demand. Indeed Markides & Geroski [15] and Johnsen et al [29] argue that explicit customer demand does generally inform incremental innovation. However, radical innovation is rarely driven by customer needs, but rather by a technology ‘supply-push’ which has its own ‘technological trajectory’.

As scientists working in a particular area collaborate and share ideas, common research themes emerge which condition those involved into developing the technology in a particular direction or ‘trajectory’ [15, p26]

*“The emergence and early development of a trajectory may look like an accident, but once the basic highway that the trajectory is going to follow becomes clear, progress along it is likely to be pretty much self-sustaining, following its own logic at a speed determined primarily by the nature of how scientists and engineers work.” [15, p29]*

Technological trajectories are discussed in more detail later in relation to innovation decision biases (2.2.4.2) and the development of firm resources (2.3.1).

The dynamic nature of innovation described in this section requires effective management of the response to external events and the innovation opportunities they present and this is the subject of the next section.

## 2.2.3 Innovation Management

There are numerous innovation management frameworks which have similar elements. For example Tranfield et al's [30, p30] 'D-R-N' (discovery-realisation-nurturing) innovation model, Cooper & Edgett's 'innovation diamond' [31, p4], Mugge & Markham's 'innovation management framework' (as cited in Kahn [32, p38]) and Tidd & Bessant's innovation model [4, p47]. Goffin & Mitchell's 'pentathlon framework' [5, p27] shown in figure 4 is typical and its five elements are used to structure this innovation management section.

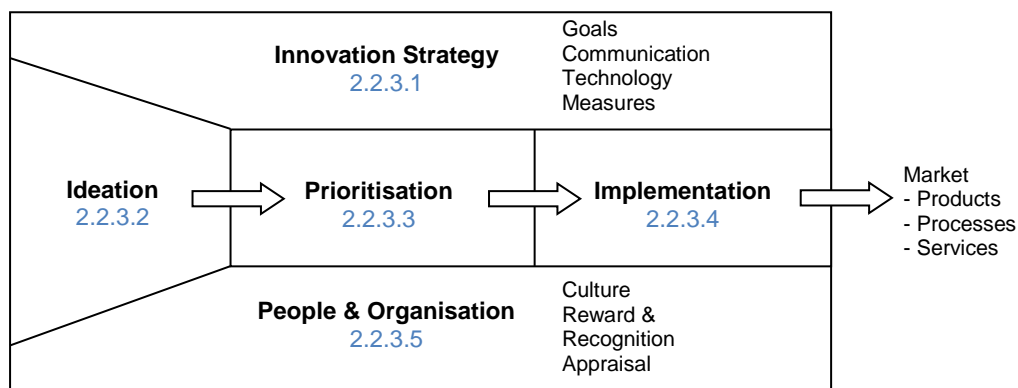


Figure 4 – The Innovation Pentathlon Framework [5, p27]

### 2.2.3.1 Innovation Strategy

Nybakk & Jenssen [33, p5] view innovation strategy as 'a structural support for innovation', effectively a framework within which its creative activities can be organised. Cooper & Edgett [31, p12] contend that innovation strategy – or 'product innovation & technology strategy' in their terminology – is initially derived from corporate strategy and informs, or provides the context for, product development programmes. The selection of 'strategic arenas' by defining market, technology and/or product areas provides both the focus for innovation and ideation, but also acts in part as a validation mechanism for new ideas.

Cooper & Edgett assert that there are two dimensions against which to evaluate the potential of strategic arenas – market attractiveness and the ability of the organisation to exploit it [31, p109]. The market attractiveness analysis they propose is a tried and tested compendium of tools and techniques that could be found in any marketing or corporate strategy textbook (for example Johnson & Scholes [34]). Understanding the firm's ability to exploit a strategic arena requires a core competency assessment.

*“The point of undertaking a core competency assessment is to help you identify adjacencies (adjacent markets, sectors, and product classes) which you can attack from a position of strength. These adjacencies become potential new strategic arenas for your business.” [31, p93]*

Cooper & Edgett's text devotes significantly more discussion to market analysis than it does to core competence assessment. The core competence evaluation also assumes a static state of affairs and does not consider how the core competencies of the organisation could or should develop over time to meet new opportunities. This is discussed in more detail in section 2.3.

The criteria used to evaluate the organisation's ability (or business strength) to exploit particular strategic arenas are suggested by Cooper & Edgett [31, p112]. For manufacturing businesses the area of operations is significantly under-represented. Notwithstanding their reference to the potential opportunities that operational strengths can bring in market and product 'adjacencies', the emphasis remains very much on 'what can we do with what we've got'. This potentially underplays operations' contribution to strategy. It infers that capital intensive production operations are effectively static – or at best play a reactive role.

Understanding the state-of-the-art of relevant technologies is critical to determining how those technologies influence business success. Visually representing the evolution of relevant technologies and their underpinning of product strategy requires 'technology roadmapping'.

*“In the context of product innovation, road mapping defines the plan for the evolution of your products; it links your innovation strategy to your plans for new products and to the technologies needed to develop them.” [31, p191]*

*“A roadmap is in many ways like a Gantt chart but at a rather high level of abstraction, the emphasis being on the logical structure and interdependencies rather than on the completeness of detail.” [5, p124]*

Phaal et al [35] provide guidance on the effective development of strategic roadmaps, while Albright & Kappel stress the importance of roadmapping looking forward as far as possible – ‘the decision to develop or acquire [technology] is a near term decision with long term consequences’ [36, p31]. However they recognise that in practice planning is not particularly predictive:

*“Much of the existing competitive intelligence in an organisation is not predictive. It focuses on today’s competitors and current products. This view is not adequate for setting technology priorities that extend beyond the next product cycle.”* [36, p34]

This section highlights the issue of the robustness of the developed product strategy. If the techniques and methods employed are insufficiently forward-looking then there is a real danger that the product strategy will be blown off course by as yet undetected influences. This is particularly damaging for capital intensive manufacturing businesses who need to ensure that long term facility commitments are sound.

Against the backdrop of a robust innovation strategy and defined strategic arenas individual ideas are generated – *ideation*.

### 2.2.3.2 Ideation

Katz [37, p31] contends that a clear focus and context for ideation is essential and that this can be achieved by carefully selected ‘strategic arenas’ within which to work. Ideation should be a balance of free-form thinking and structured processes, for example Corning’s ‘Magellan Process’ (as cited in Kahn [32, p167]) which combines innovation workshops and in-depth opportunity analysis.

Cooper [6] suggests three categories of ideation approach. The first of these are traditional ‘Voice of the Customer’ (VoC) methods including, for example, customer focus groups and customer advisory boards [6, pp162-172]. These are generally well-established techniques, and are deemed to be effective for incremental and architectural innovations, but are less so for more radical innovation. Cotterman observes that *“traditional tools like focus groups are not good to identify new technology and new trends”* [38, p18].

Cooper’s second group of ideation methods use sources external to the firm for inspiration, for example partners, suppliers and academia [6, pp181-186]. These ‘open



innovation' methods build on the work by Chesbrough 2003 [39] who observed that moving from a closed innovation paradigm to a more open one is critical in today's technological environment. He states that there are implications throughout the strategy and product development process – this is discussed more fully in section 2.2.3.5

Thirdly, Cooper suggests strategic methods for stimulating innovation and ideation using similar methods to those used to select strategic arenas [6, pp172-181]. Alongside the standard market analysis tools are the more predictive tools which seek to address earlier concerns about the robustness of strategy development in the face of uncertainty. These include scenario planning and periphery scanning which are discussed further in section 2.2.5. These methods are designed to unearth potential competitive, technological, regulatory and environmental changes earlier in the strategy development process to ensure evolved strategy is fit for the future.

Kim & Mauborgne in their 'Blue Ocean Strategy' [40] identify that traditional marketing approaches need to be re-considered to ensure opportunities are not missed in a rapidly changing environment. They contend that companies must stop competing (solely) in 'red oceans' where competition is fierce for a defined level of available business. Success here is gained by removing market share from others through incremental business and/or product improvements. In 'blue oceans' the competition is irrelevant (at first) because the rules of the game are yet to be set.

*“Yet the overriding focus of strategic thinking has been on competition-based red ocean strategies. Part of the explanation for this is that corporate strategy is heavily influenced by its roots in military strategy ... Described this way, strategy is about confronting an opponent and fighting over a given piece of land that is both limited and constant ... To focus on the red ocean is therefore to accept the key constraining factors of war – limited terrain and the need to beat an enemy to succeed – and to deny the distinctive strength of the business world: the capacity to create new market space that is uncontested.” [40, pp6-7]*

Whichever ideation processes are employed, the resulting potential opportunities will then need to be prioritised.

### 2.2.3.3 Prioritisation

Idea management systems are required to sort and filter the output of the ideation activity. Idea selection methods are often 'balanced scorecards' with a mix of financial and non-financial metrics [5, p204] [31, p215] [41, p179 & p194]. Typically these metrics are focused on outward-looking dimensions and relatively few are rooted in the existing operational competences of the organisation.

Idea selection in incremental innovation situations is relatively straightforward, but in radical or discontinuous situations organisations face challenges. Decision-making here requires subtly different approaches if potentially significant new opportunities are not to be screened out by evaluation criteria designed for use in more familiar technological territory. Once the uncertainty surrounding radical opportunities subsides it may then be possible to revert back to established decision-making process [4, p344].

*"An alternative strategy is, of course, to adopt a 'wait and see' approach and allow the market to deal with early stage uncertainty. By taking a 'fast second' posture large and well-resourced firms are often capable of exploiting innovation opportunities more successfully than smaller early entrants."* [4, p346]

This 'wait and see' approach introduces the debate between 'deliberate' and 'incremental' (or 'emergent') planning and this is discussed further in section 2.2.5.

Beyond assessing the merits of individual ideas, the balance of the organisation's suite of innovation projects should be considered. A project portfolio approach is usually taken to spread the risk between incremental and more radical innovation [5, p190]. Portfolio management ensures strategic alignment through allocating resources into strategic themes or 'buckets' in appropriate proportions [5, p211] [6, p250].

Once projects have been prioritised and a strategically appropriate balance of projects established, resources are allocated in order that innovations are realised through the implementation process.

#### 2.2.3.4 Implementation

Cooper's stage-gate approach [6, 41] has become the template for controlled, efficient product development implementation processes. The 'stages' of concept, feasibility, design, pre-launch testing and launch linked by robust 'go/no go gates' is familiar in many businesses [6, pxiii].

Cooper [6] strongly links the success of product development projects with the level of alignment of market needs/business wants and the resources of the organisation.

*"... the ability to leverage existing and in-house strengths, competencies, resources, and capabilities increases the odds of success of the new product project. By contrast, 'step-out' projects take the firm into territory that lies beyond the experience, competencies, and resource base of the company and increase the odds of failure."* [6, pp61-62]

In fact, Cooper claims that if such synergy or alignment can be achieved then this typically leads to more than doubling of market share and significantly increased profitability [6, p63]. If alignment of needs and resources is so important to success it implies that the development of resources must anticipate new product development projects because such resources and manufacturing equipment take time to put in place. This implies the need for an *anticipatory* product strategy development process and brings into question why there is not a higher degree of focus on existing operational capabilities within 'strategic arena selection' when developing innovation strategy.

The issues discontinuous innovation bring to the product definition and development process are also discussed by Lynn et al [42] and Bessant et al [43]. The archetypal stage-gate development process, so well-suited to incremental product improvements, has severe limitations when discontinuities are introduced.

*"What may be sound practice for the development of incremental improvements may be inapplicable – or worse, detrimental – to the development of discontinuous innovations ... The familiar admonition to be customer-driven is of little value when it is not at all clear who the customer is – when the market has never experienced the features created by the new technology."* [42, p11]

Lynn et al's research into discontinuous innovations revealed that market research was conducted as it would have been for incremental innovation, but almost none was used and much of it was misleading [42, p13]. This view is echoed by Tidd & Bessant:

*“Good practice of the ‘steady state’ kind ... can actively militate against the entry and success in the fluid phase of a new technology ... How do they understand the needs of a market which doesn't exist yet but which will shape the eventual package which becomes the dominant design? If they talk to their existing customers the likelihood is that those customers will tend to ask for more of the same.”* [4, pp45-6]

*“As Henry Ford is reputed to have said, ‘if I had asked the market they would have said they wanted faster horses!’ ”* [4, p266]

Florén & Frishammar identify that idea and concept development are key disciplines that are required for all new product development projects but that they are inevitably more ‘messy’ and difficult for radical innovation [44, p32]. Koen et al [45] and Matheson [46] also warn against overly prescriptive new product development processes lest they stifle the very innovation they are meant to realise.

Cooper himself acknowledges that his stage-gate approach needs to be more adaptive and agile to be effective at delivering radical innovations [47, p21]. Holahan et al [48] also contend that new product development processes need to be adapted according to the level of innovation.

In lieu of the typical ‘stage-gate’ process management tool a ‘probe-learn’ model has been recommended as more appropriate for discontinuous innovation [4, 42, 44, 49]. A probe-learn process essentially involves producing early prototypes and testing them iteratively, typically over long cycles as technologies and markets develop. Each probe cycle leads to learning for subsequent cycles – but not in an ordered or predictable way. Market testing at this early stage is very different to that typically used at the end of a stage-gate process. It is an experimental rather than an analytical process due to the higher levels of uncertainty.

*“Often, new concepts are not customer-generated and cannot be amenable to up-front market research. Instead, attention is focused on explicating the technical differential advantage that a new concept will offer over existing products and technologies. Thus, for very novel concepts, most potential*

*users do not have the real-world experience needed to provide accurate data and propose solutions.” [44, p32]*

MacCormack [50] observes that the type of new product development process is also influenced by the business context of the organisation. For example in successful technology start-up businesses product development processes tend to be more of the probe-learn type rather than the more rigid stage-gate approach.

More recently Cooper & Sommer [51] propose adaptations to the traditional stage-gate process to improve its agility. These tools, borne out of the software industry, have proven to be applicable to physical product projects too. The ‘agile’ techniques employed place more emphasis on individuals, collaboration and responding to change rather than rigid processes, tools and documentation.

The elements of innovation management discussed above – innovation strategy, ideation, prioritisation and implementation – operate in the context of the people and their organisation within the business. This context is reviewed in the next section.

### **2.2.3.5 People & Organisation**

At its most fundamental level innovation is driven by individuals’ knowledge and therefore creating an environment that facilitates learning is critical. Richtnér & Åhlström argue that

*“... the knowledge creation process is the central process through which companies create innovation, and better management of the knowledge creation process should be a central issue in most companies.” [52, p1009]*

Knowledge can be grown organically within the organisation and, indeed, Cooper’s original stage-gate premise in the early 1990’s [41] made the assumption that all stages of the product development process were wholly internal to the organisation. It has been shown by Chesbrough [39] that in recent decades there has been a much more ‘open’ approach to innovation that has pervaded industry. Chesbrough illustrates the concept of *open innovation* by comparing the traditional ‘Closed Innovation Paradigm’ to the current ‘Open Innovation Paradigm’ in relation to the management of R&D.

### **Closed Innovation Paradigm:**

Refers to the highly vertically integrated approach of post-war companies where research, development, commercialisation and route-to-market of new technologies and products were held within the boundaries of the organisation. Companies would develop a buffer of potentially exploitable technologies between its research and development functions that would be commercialised at the point where there was some alignment between the technology and the organisation's business model. The approach was exemplified by 'idea funnel' and 'stage-gate' development processes.

### **Open Innovation Paradigm:**

Knowledge and expertise used in the course of R&D and new product introduction is not wholly generated from within. External ideas are used to generate core products for the business and equally, internally generated intellectual property (IP) that may not fit the current business model is not left to gather dust between research and development functions, but is exploited through licensing, spin-off businesses or venture capital. The role of IP has therefore become more active by moving from 'hoard and protect' to 'utilise or license'. The trading of IP – both into and out of the business – becomes a critical function [39, p57].

Chesbrough [28, p111 & p132] provides a graduated categorisation of the level of an organisation's open innovation and the degree of integration into its corporate strategy – a measure of its innovation posture which will be discussed in section 2.2.4;

- |                     |  |
|---------------------|--|
| 1. Undifferentiated | No innovation                          |
| 2. Differentiated   | Ad hoc innovation                      |
| 3. Segmented        | Planned innovation                     |
| 4. Externally aware | Looks outside for innovation           |
| 5. Integrated       | Innovation is linked to business model |
| 6. Adaptive         | Identifies new business models         |

Open innovation principles can be applied at any and all stages of the product development process from ideation through to product launch. Enkel et al [53] and Andrew & Sirkin [54] contend that the 'closed' and 'open' paradigms described above represent the ends of a spectrum and that in most businesses there is a mix of closed and open innovation.

A more open approach to innovation can improve speed and agility in product development, but too much openness can lead to a loss of control and dilution of core

competences. So the aim should be to strike a balance between improving speed and innovativeness in product development by the introduction of an open innovation approach, while at the same time building on core competencies and protecting IP.

*“Too much openness can negatively impact companies’ long-term innovation success, because it could lead to loss of control and core competences .... The future lies in an appropriate balance of the open innovation approach.” [53, p312]*

In a similar vein Madsen & Leiblein’s [55] analysis on the persistence of innovation advantage concludes that the advantage derived from internal knowledge typically lasts twice as long as that derived from external partners.

Gassman et al’s [56] review of the state of research into open innovation recognises the importance of the culture of the firm in determining the effectiveness of employing external innovation sources. Individuals within the organisation must come to value external competence and know-how for an open innovation approach to be successful.

Docherty also discusses the cultural challenges involved in blending internal and external sources of innovation

*“... making open innovation happen requires overcoming the significant barriers and perceived risks on the people side of the equation.” [57, p15]*

The organisation’s attitude to risk as well as that of individuals within it will shape both the appetite for innovation – whether in ‘closed’ or ‘open’ form – and its potential success. This leads to the next section which discusses further a firm’s ‘innovation posture’ and the decision biases that accompany innovation management.

## 2.2.4 Innovation Posture & Propensity

Innovation strategy development is not a wholly sterile and deterministic process – it operates in an organisational climate created by the management team's beliefs and attitudes [58]. Acur et al define this innovative climate as

*“... composed of a learning philosophy, strategic direction, and trans-functional beliefs that, in turn, guide and direct all organizational strategies and actions, including those embedded in the formal and informal systems, behaviours, and competencies, and processes of the firm to promote innovative thinking and facilitate successful development, evolution, and execution of innovation.”* [58, p918]

The combination of the organisation's innovative climate with the necessary alignment of innovation strategy with the wider business strategy (Acur et al [59]) results in the innovative *posture* of the firm. Calantone & Rubera define innovation posture as ‘a reflection of a firm's commitment to developing and marketing products that are new to the firm and/or the market’ [60, p148].

Innovation posture can be seen as *aggressive*, with many product introductions that lead the competition, or *defensive*, with few new products and only then in response to competitors' actions [60, p148]. Griffin & Page [61] propose a more granular typology with their innovative posture types – *prospector* (innovator), *analyser* (fast follower), *defender* and *reactor*.

This link between competitive strategy and an attitudinal aspect to innovation is also reflected in Dobni's [62] innovation ‘orientation’ model. Dobni contends that a key component of innovation orientation (or posture) is its *intention* to innovate – its innovation *propensity*. Dobni describes innovation propensity as the

*“... degree to which the organisation has a formally established architecture to develop and sustain innovation ... communicated through vision, goals [and] objectives...”* [62, p341]

The likelihood that systems and procedures are formally established to support innovation in this way will be influenced by the relative emphasis that is placed on exploiting existing knowledge compared to the exploration of new knowledge [60]. The ability to do both has been termed *ambidexterity*.



Management choices in terms of resource allocation for explore and exploit activities will be affected by personal and group decision biases within the senior management team.

These two aspects of innovation propensity – ambidexterity and management decision biases – are discussed in the next two sections.

#### 2.2.4.1 Ambidexterity

An aspect of an organisation's innovation propensity is its determination and ability to strike a balance between exploiting the current and exploring the future [4, p205] as briefly discussed in section 2.2.1. Levinthal & March's [63, 64] early thoughts include;

*“An organisation that engages exclusively in exploration will ordinarily suffer from the fact that it never gains the returns of its knowledge. An organisation that engages exclusively in exploitation will ordinarily suffer from obsolescence. The basic problem confronting an organisation is to engage in sufficient exploitation to ensure its current viability and, at the same time, to devote enough energy to exploration to ensure its future viability.”* [64, p105]

Put more pointedly by Hall (as cited in Tidd);

*“Is it possible to organise one's corporate affairs so that the formal organisation sweats the assets whilst the self-adaptive informal organisation produces the fundamental changes which will be required to create new strategic competencies?”* [65, p40]

Simsek defines organisational ambidexterity as *‘the state of attaining exploitation and exploration with dexterity, or achieving high levels of both’* [66, p602].

Brion et al [67] propose that focus must be given to developing the explorative aspects in preference to the exploitative because this has a more direct and significant effect in creating innovation ambidexterity. This is likely to be due to March's observation that competence exploitation is a more natural state for most firms and this must be offset by conscious exploration [63, p73].

Floyd & Lane recognise the bias towards exploitation and that there is a

*“conflict between the need to institutionalize the managerial behaviour associated with current competencies and current strategies and the need to encourage the behaviours necessary to develop new competencies and new strategies.” [68, p154]*

O’Reilly & Tushman [69] and Andriopolous & Lewis [70] concur that this conflict presents managers with very difficult challenges. The track record of businesses being effective at both exploring and exploiting is not good. Christensen is pessimistic and suggests new business models need to be spun out of the main organisation to deal with the two different structures that are required [12, p102].

There is an argument that ambidexterity can occur sequentially as periods of exploration are followed by the exploitation of the knowledge gained, until it is time to explore again. This has been variously termed ‘temporal’, ‘sequential’, ‘punctuated equilibrium’ or ‘vacillation’ ambidexterity (Gupta et al [71], Raisch et al [72], Simsek et al [73] and Boumgarden et al [74] respectively). However, more recent analysis by Swift warns of the ‘perilous’ transitions between periods of exploitation and exploration:

*“...we are able to observe firm performance as firms are making the attempt to transition between these opposing forms of R&D-based innovation, and observe organisational mortality rates as the process unfolds. Analysis ... shows that the magnitude of compact, significant changes in [exploitation and exploration], in either direction, is associated with a higher incidence of firm mortality.” [75, p1689]*

In any event, O’Reilly & Tushman [69] suggest this sequential approach is insufficient in rapidly changing markets – managing exploitation and exploration simultaneously is the ideal – but they admit this is difficult in practice.

Gibson & Birkinshaw [76, p211] describe exploitation and exploration activities in slightly different terms by defining organisational ambidexterity as the reconciling of current task management (*alignment*) with the need to be *adaptive* enough to enhance their long term competitiveness. The typical solution proffered (for example by De Visser et al [77], Gassman et al [78] and Blindenbach-Driessen et al [79]) is to put in dual structures – “one focused on alignment while the other focuses on adaptation” – this is termed ‘structural ambidexterity’. However, Gibson & Birkinshaw argue that the best way to achieve ambidexterity is not to impose structural delineations within the

business (which incurs coordination costs) but to foster the ‘behavioural orientation’ of individuals.

*“... [ambidexterity] is best achieved not through structural, task, or temporal separation, but by building a business unit context that encourages individuals to make their own judgments as to how best divide their time between the conflicting demands for alignment and adaptability.” [76, p211]*

This adaptation of individuals’ approach under different situations has been defined as ‘contextual ambidexterity’, by McCarthy & Gordon [80] and Raisch et al [72], among others. Berghman [81] and Durisin & Todorova [82] argue that a contextual approach during the initial explorative innovation phase, followed by a structural approach during commercialisation yields the best results.

Patel et al [83] contend that structural ambidexterity may be an adequate approach for larger firms, but for smaller firms it could be too inefficient. Lubatkin et al [84] argue that senior management teams in SME’s are better placed in some respects because they are closer to the operational core of the business, understand the firm’s core competences better and are likely to be driven to be explorative earlier than in a large firm.

*“Organizational ambidexterity may not be as difficult or illusive for firms to achieve as some in the literature believe ... Our findings suggest that senior managers of larger firms in search of greater ambidexterity may want to reconsider creating structurally separate business units that focus on either exploitation or exploration, and instead strive to create business units that are capable of pursuing both.” [84, p668]*

Ultimately it may just be the competitive environment which acts as a constraint on firms’ explorative ambition. Zschocke et al [85] make the case that competition itself drives firms towards incremental, exploitative new product portfolio investments.

The choices management teams make in allocating resources to exploitative and explorative activities is as a result of a combination of rational decision-making and their subconscious decision biases. These biases are discussed in the next section.

### 2.2.4.2 Decision Biases

In most organisations, the culture, processes and the organisation itself have been developed over time as a direct result of past successes. This often leads to Levinthal & March's 'success trap' where the relatively quick rewards that result from exploitation is positive feedback that encourages firms to do more of the same – *exploitation drives out exploration*' [64, p107]. Prahalad [86] argues that this success trap arises from the firm's 'dominant logic' which is the 'DNA of the organisation'.

*"It is embedded in standard operating procedures, shaping not only how the members of the organisation act but also how they think. Because it is the source of the company's past success, it becomes the lens through which managers see all emerging opportunities."* [86, p172]

This dominant logic is helpful in stable environments because it streamlines decision-making, however in turbulent environments it can 'blind' organisations, making it hard to detect new threats and opportunities [86, p172]. The pitfall occurs when innovations fall outside the current business model. Here 'false negatives' are created when evaluating more radical opportunities because the closed innovation metrics don't account for alternative business models [86].

The firm's dominant logic optimised as a result of realising opportunities close to the core business, potentially excludes other possibilities from serious consideration. Several authors make essentially the same point, for example, Chesbrough [39] and Goffin & Mitchell [5] respectively;

*"A business model is a double-edged sword for the corporation ... An effective business model creates an internal logic of its own for how value is created and claimed. Every subsequent opportunity is evaluated in the context of this dominant logic."* [39, p90]

*"The disciplines of running a mature organisation are very challenging and they become deeply embedded in the culture ... of the company. The trouble is that these habits can be quite wrong for handling something really novel. The most successful companies often find change most difficult because they have the most to change."* [5, p131]

The psychological orientation of individuals can be affected by the degree to which a dominant design has been established (see figure 3). Product innovation then becomes

focussed on a core set of possibilities – the ‘technological trajectory’. Interest and resources are channelled on possibilities within the ‘dominant design corridor’ (this is discussed further in section 2.3.1).

*“Organisations build capabilities around a particular trajectory and those who may be strong in the later phase of an established trajectory often find it hard to move into an new one .... This is partly a consequence of sunk costs and commitments to existing technologies and markets and partly because of psychological and institutional barriers. They may respond but in slow fashion – and they may make the mistake of giving responsibility for the new development to those whose current activities would be threatened by a shift.” [4, p45]*

Petrick & Martinelli propose a strategic roadmapping process to encourage a forward-looking, external view of the technological landscape, which is difficult to establish for successful incumbent firms because it requires individuals to develop a view of the future that their peers don’t possess [87, p49].

*“Strategic roadmapping works particularly well for successful incumbent companies in established markets who desire to embark on a non-incremental path, weakening the stranglehold of their dominant logic.” [87, p57]*

If dominant incumbent business models falsely excluding potentially lucrative new ideas is problematic, then the situation is even worse when an established business is threatened by competitive disruption. Christensen [13] states that

*“Disruption has a paralysing effect on industry leaders. With resource allocation processes designed and perfected to support sustaining innovations, they are constitutionally unable to respond.” [13, p35]*

So new market disruptions generally cause incumbents to ignore the entrants and low-end disruptions cause established companies to flee the attack up-market. Gilbert & Bower [88] (and subsequently Gilbert [89]) support Christensen’s point that the response to disruption is heavily influenced by existing processes and a concerted effort is required to act in the most effective manner. It is here where core competencies can turn into ‘core rigidities’ and prevent the business taking a new direction (see also section 2.3.1).

This section has shown how a firm's innovative posture and innovative propensity will influence the development of the firm's overarching business strategy. It will objectively inform, but also subconsciously predispose managers to particular courses of action. The strategic management literature described below provides the context within which these decisions are taken.

## 2.2.5 Strategic Management

Porter's competitive forces approach [90] has been a dominant philosophy in the strategic management literature. In Porter's paradigm assets, resources and skills are deemed equally accessible to all players in an industry. Firms establish competitive advantage by impeding one or more of Porter's five forces that would otherwise drive the total economic returns of the competitive system to zero. 'Strategies are aimed at altering the firm's position when compared to customers and suppliers' [91, p511]. The structure of the industry is key as competitive advantage is based on altering the dynamics of competition.

The pre-eminence of this outward-looking approach is reflected in the methods to determine innovation search arenas [31], ideation evaluation criteria and product development prioritisation [4, 6, 41] discussed in section 2.2.3. The importance of an organisation's resources in strategy formulation is effectively downplayed by the dominant consideration of criteria external to the firm.

Uncertainties in the market or technological environment undermine the effectiveness of firms' strategic and innovation management processes that are designed to operate under steady-state or 'normal' conditions. Christensen [12, 13] observes that the ability for established companies to identify innovation opportunities – and potential threats – in the periphery of their vision is often compromised by their predisposition with incremental or sustaining innovations.

Bessant & Francis [22] suggest ways to deal with disruptive events arising from environmental turbulence. These include ensuring resource allocation approaches encourage both exploitative and exploratory innovation, making sure that the firm is aware of its own decision biases so that 'inconvenient' information is not rationalised away, and critically that the firm is aware of developments at the periphery of its knowledge base [22, p22].

Day & Schoemaker contend that *'often the early warnings of pending turmoil are faintly visible at the periphery'* and recommend that a formal process is included in strategy development to try to tease out these relatively small signals [92, p12]. This discipline of extending the firm's 'peripheral vision' helps to prevent such weak signals from being inadvertently passed over, effectively ignoring potential threats and opportunities.

*"Without conscious intervention, the mind will naturally force fit any faint inclinations into pre-existing mental models. When subjects are shown a red spade in a deck of cards, for example, they often identify it as a heart because they force this anomalous card into the well-known model of the standard four suits. But a viewer who has entertained the possibility of a red spade may be able to see it."* [92, p12]

In a similar vein, Nicholas et al [93] identify 12 search strategies designed to explore a firm's periphery and to ensure they escape their existing cognitive frames. These are divided into those that have an exploitative focus and those that are more explorative. Exploratory searches must overcome 'inattentional blindness' – *'the failure to see what should not be there'*. [93, p28]

*"Every innovation will eventually face the end of its life-cycle. Rather than approaching this endpoint with apprehension, companies should recognize that long-term survival is contingent on launching the next S-curve and pursue strategies to identify that next curve. Thus, radical innovation and opportunity identification must become embedded capacities rather than standalone activities."* [93, p34]

Many authors provide guidance to allow firms to fully explore their periphery and to look as far into the future as possible. For example, Schwartz's 'Scenario Planning' [94], and Christensen et al's 'Seeing What's Next' [95].

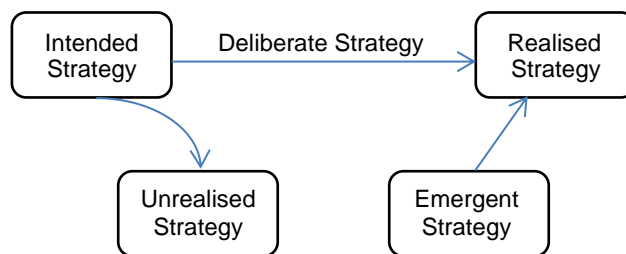
In spite of the rational, somewhat formulaic, approach to strategic and innovation management, several authors recognise that due to the turbulent nature of the environment the process in practice is much more incremental in nature. Quinn [96] presents a picture of strategy evolving incrementally over time as new information comes to light and the impact of previous decisions becomes apparent.

*"The approaches [managers] use frequently bear little resemblance to the rational-analytical systems so often described in the planning literature ...*

*the real strategy tends to evolve as internal decisions and external events flow together to create a new, widely-shared consensus for action among key members of the top management team.” [96, p34]*

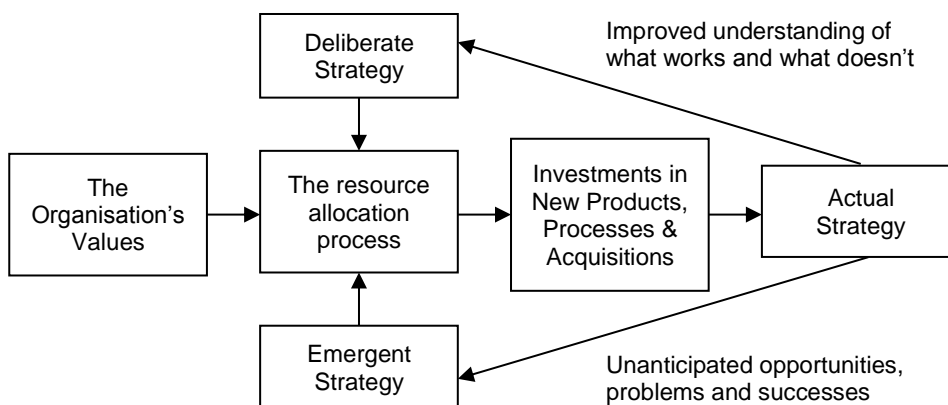
Quinn argues that this ‘logical incrementalism’ is ‘not muddling’, rather ‘conscious, purposeful, proactive, good management’ [96, p36]. Chesbrough’s analogy here is that deliberate planning is like playing chess where all information is available and moves can be planned in advance, whereas incremental or ‘emergent’ planning is more akin to playing poker where information is revealed more gradually [39, p13].

Emergent strategy was defined as early as Mintzberg in 1978 [97] and his model of strategy formulation is shown in figure 5.



**Figure 5 – Strategy Formulation**  
(Mintzberg 1978, as cited in Mirabeau & Maguire 2014 [98, p1204])

Mirabeau & Maguire contend that ‘*the strategy literature emphasizes deliberate rather than emergent strategy*’, and that strategy is ‘*an iterated process of resource allocation*’ [98, p1202]. Christensen [13] argues that deliberate and emergent processes are always at work in developing strategy, although perhaps not consciously, and illustrates this point in figure 6.



**Figure 6 – Strategy Definition & Implementation**  
(Christensen [13, p215])



Similarly to Mirabeau & Maguire, Christensen [13] emphasises the central role the resource allocation process plays and this is also reflected in Atuahene-Gima's [99] investigation into achieving the ambidextrous balance between exploitative and explorative innovation. However, as recently as 2017 Maritan & Lee [10] were surprised to find that there is not more research into the area of resource allocation in support of firm strategies. Section 2.3 considers in some detail the role firm resources can and should play in competitive strategy.

Deliberate and emergent strategy development require different processes, evaluation mechanisms and organisational approaches. These are shown in table 4 which is an adaptation of tables from Christensen [13] and Phillips et al [23].

**Table 4 – Contrasting Strategy Development Approaches**  
(Adapted & abridged from Christensen [13, p228] & Phillips et al [23, p183])

<b>Steady-State/Incremental Innovation Deliberate Planning</b> <i>Based on numbers and rules</i>	<b>Discontinuous/Disruptive Innovation Emergent/Discovery-Driven Planning</b> <i>Based on pattern recognition</i>
<ul style="list-style-type: none"> <li>• Make assumptions about the future</li> </ul>	<ul style="list-style-type: none"> <li>• Tune in to weak market signals</li> <li>• Develop scenario planning</li> <li>• Bring in outside perspectives</li> <li>• Create target financial projections</li> </ul>
<ul style="list-style-type: none"> <li>• Define strategy based on those assumptions, and build financial projections based on that strategy</li> </ul>	<ul style="list-style-type: none"> <li>• What assumptions must prove true in order for these projections to materialise</li> <li>• Explore alternative future scenarios</li> <li>• Identify strategic domains for targeted hunting</li> <li>• Build capacity for ambiguity/parallel strategies</li> </ul>
<ul style="list-style-type: none"> <li>• Make decisions to invest based on those financial projections</li> <li>• Implement the strategy in order to achieve the projected financial results</li> <li>• Use a systematic process for new product development e.g. Stage-gate</li> <li>• Close monitoring &amp; evaluation at each stage</li> </ul>	<ul style="list-style-type: none"> <li>• Implement a plan to learn – to test whether the critical assumptions are reasonable</li> <li>• Invest to implement the strategy</li> <li>• Build pluralism into the portfolio management decision-making processes</li> <li>• Decentralise seed funding for new ideas</li> <li>• Build dual structures for innovation and decision making</li> </ul>
<ul style="list-style-type: none"> <li>• Early involvement of all relevant functions – inside and outside the firm</li> <li>• Active user involvement in early stages</li> </ul>	<ul style="list-style-type: none"> <li>• Emphasise probe-learn rather than stage-gate for project development</li> <li>• Build parallel resource networks</li> </ul>
<ul style="list-style-type: none"> <li>• Cross-functional team working</li> <li>• Concurrent engineering</li> <li>• Use of tools, e.g. CAD, rapid prototyping</li> </ul>	<ul style="list-style-type: none"> <li>• Develop pro-active, non-committal exploratory supply relationships</li> </ul>
<ul style="list-style-type: none"> <li>• Continuous improvement culture</li> <li>• Carry forward lessons learned</li> </ul>	<ul style="list-style-type: none"> <li>• Encourage curiosity-driven behaviour</li> <li>• Encourage heterogeneity in learning group</li> <li>• Enhance absorptive capacity</li> </ul>

Balancing deliberate and emergent planning activities in the same organisation is difficult given the significant differences in approach required. The ability to do this effectively has been termed 'ambidexterity' – a term that has been used in section 2.2.4

with reference to the balance between innovation exploitation and exploration. There are conceptual similarities between innovation ambidexterity and strategic management ambidexterity.

In simple terms an emergent strategy development approach should be used when the situation is hard to read – i.e. during periods of radical or disruptive innovation – and a more rationalist (or deliberate) approach should dominate once a winning strategy becomes clear – i.e. during steady state periods of incremental development.

Teichert & Bouncken 2011 [100] examine the constraints placed on both deliberate and emergent planning, and conclude that supply chain rigidities stifle the contribution of an emergent approach.

*“An emergent strategy’s power lies in intuition, experimentation, creativity, and autonomous testing associated with trial and error. This is not available under high rigidities that may change quickly and exert strict and formal limitations to autonomous creativity and innovation development. Hence, the freedom the emergent strategy approach requires does not exist in an environment of high supply chain rigidities.” [100, p99]*

Emergent planning therefore implies a degree of agility to respond and adapt to critical information as it becomes apparent.

*“Research has revealed that agility to react fast to new opportunities is rated above the ability to foresee and plan further into the future; this reflects the short-term perspective of most organisations. Paradoxically, agility is enhanced by a longer perspective; those who are vigilant in scanning their operating environments and plan further ahead, tend to be better prepared and more agile.” [18, p67]*

Eshima & Anderson’s [101] investigation into firms’ adaptive capability, or agility, concludes that firm growth has a part to play. They argue that as a firm grows and expands its resource base it becomes inherently more agile as there are more opportunities for new resource combinations to better serve existing markets. Resources and their contribution to the competitive opportunities available to the firm are central to the next section (2.3) of this literature review.

## 2.2.6 Innovation & Strategic Management Literature Summary

Key themes from the innovation and strategic management body of literature are presented below with selected references cited.

- It is critical that organisations innovate in order to facilitate growth and ensure longevity [2, 3]. The technological and market environment, the current technology and capabilities available to the firm, and the innovative posture that the senior management team adopt will combine to influence the type, the timing and the effectiveness of the innovative efforts of the firm [62].
- The literature on innovation management, innovation strategy and product development practice is dominated by addressing the opportunities and threats from the competitive environment in the manner encapsulated in Porter's competitive forces approach. The role existing resource and skill assessment plays in ideation and idea selection/prioritisation is significantly, and detrimentally overshadowed by market analysis [31, 90].
- Strategic ideation techniques must identify potentially discontinuous or disruptive innovations – either as opportunities or threats – in sufficient time to respond effectively [92, 95]. Discontinuous innovations are most effectively brought to market using a 'discovery-driven' or 'probe-learn' development process rather than the more traditional 'stage-gate' product development process [42].
- A firm's innovative efforts occur in the context of its innovative climate and the attitudes of its senior management team. The resulting innovation propensity directly affects its competitive strategy [62].
- Organisations are encouraged to be 'ambidextrous' – to be able to both *exploit* existing skills and opportunities and to appropriately *explore* and develop new ones [64]. This is a difficult balance to achieve [68].
- The business models, processes and culture of an organisation will be the result of past successes (and failures) and often lead to resource and routine rigidities [86]. They are likely to deliver 'false negatives' when evaluating radical or discontinuous innovations and leave firms vulnerable to new market entrants [13].
- There are usually both deliberate and emergent strategy development processes operating in an organisation – even if the emergent mode is not declared or acknowledged [13, 96, 98]. These modes of strategy development combine to influence the allocation of available organisational resources to product development, firm processes and equipment acquisitions [10, 13].

## 2.3 Resource & Manufacturing Strategy

### 2.3.1 The Resource-Based View of the Firm

Having seen Porter's contribution to the strategic management literature in section 2.2.5, there is a widely held view that his outward-looking view of strategy has not only been dominant in strategy development but is also significantly limited. Bhamra et al [102] suggest that:

*"The resource-based view can be seen as an alternative approach towards strategy, where the dominant convention had been the competitive positioning approach as championed by Porter."* [102, p2729]

Augier & Teece [103] are explicit regarding the limitations of Porter:

*"Porter's Five Forces framework is insightful but limited because it is devoid of any meaningful conceptualization of the firm. With respect to how firms actually differentiate, the Porter framework sees this occurring basically through the product choices they make. There is little attention given to the enterprise itself or the capabilities of management."* [103, p1189]

Barney [104] contends that unlike Porter's assumptions that resources are homogenous across an industry (or can be relatively easily made so by investment and training) the resource-based view (RBV) of the firm takes into account that many resources are idiosyncratic to the firm and often immobile between businesses.

Maritan & Peteraf [105] build on earlier work by Dierickx & Cool [106] and examine the mechanisms that drive heterogeneous resource positions, and key amongst these are that some resources are non-tradable and that they cannot be obtained on the open market.

Several authors (Amit & Schoemaker [107], Ahuja & Katila [108], Kunc & Morecroft [109], Ndofor et al [110] & Schmidt & Keil [111]) explain that the complexity of the competitive environment coupled with imperfect managerial decision-making contributes to firms' resource and capability asymmetries which cannot occur in a purist Porter world. Wernerfelt [112] underlines this with references to chaos theory in the way that small initial differences can lead to substantial differences over time.

Teece [91] argues that under the RBV resources are heterogeneous and 'sticky' because:

*"... firms lack the organizational capacity to develop new competences quickly ... some assets are simply not readily tradable, for example, tacit know-how and reputation ... Firms are to some degree stuck with what they have and may have to live with what they lack."* [91, p514]

It's not just about what market opportunities there are but what resources a firm has – and contrary to Porter's approach these resources are often not simply tradable.

*"What becomes clear is that firms cannot expect to 'purchase' sustained competitive advantages on open markets. Rather, such advantages must be found in the rare, imperfectly imitable, and non-substitutable resources already controlled by a firm".* [104, p117]

A similar juxtaposition to the Porter-RBV comparison is developed over a series of three papers by Paladino [113-115] in which she discusses the relationship between the *market orientation* and the *resource orientation* of an organisation. A resource orientation causes

*"... firms [to] devote effort to generating a resource base that will be difficult and costly, if not impossible, to imitate. It then uses this resource base to exploit opportunities or to neutralize threats that arise in the external environment."* [113, p535]

This is contrasted with market orientation which focuses on creating behaviours that lead to superior value for customers. Paladino contends that resource orientation improves firm performance through effective new product development, whereas market orientation improves performance through adding customer value.

Paladino's examination of the effect of environmental turbulence shows that in practice management teams find it very difficult to employ a market orientation in times of high turbulence, whereas the opposite is true of the effect on resource orientation:

*"...when the rate of technological turbulence increased, the relationship between resource orientation and innovation was strengthened ... When technological innovations take place ... the need for a focus on the*

*development and application of organizational resources increases.” [114, p590]*

The core competence literature emerging from RBV from Penrose 1959 [116], Wernerfelt 1984 [117], Prahalad & Hamel 1990 [118] and Barney 1991 [104], through to Teece 1997, 2009 & 2012 [91, 119, 120] emphasises the need to recognise that a firm's competences are hard-won assets that are difficult to imitate.

These skills and competences that have been developed over time as a result of firm-specific decision-making within its local commercial and technological environment contribute to the 'technological trajectory' of the firm (a term that has previously been applied to the evolution of products, see section 2.2.2).

Teece [91] describes a firm's technological trajectory as the technological *path* the business has travelled and the technological *paths* currently open to it.

*“... the competitive advantage of firms lies with its managerial and organisational **processes**, shaped by its (specific) asset **position**, and the **paths** available to it.” [91, p518]*

Tranfield et al [30] describe these key elements. **Position** is the firm's 'current endowment of technology', its key customer/supplier relationships and core competences, which are the result of cumulative learning and not easily replicated. **Path** is the organisation's strategic direction and technological trajectory, which have been shaped by prior experience – this is often neglected in other strategy models. **Processes** are how an organisation has learned to behave, its routines and culture. They evolve over time and are difficult to imitate.

Teece et al, (as cited in Hall [65, p26]) and Greve & Seidel [121] agree on the idiosyncratic nature of resources and the strategic competences they unlock;

*“... [resources] are firm specific ... a function of the knowledge and experience that the firm has acquired over time. This is in essence a recognition of the path-dependent nature of organisational processes and routines and their roles in carrying knowledge.” [119, p117]*

Leonard-Barton [122, 123] states that these core capabilities are 'institutionalised' and 'reflect accumulated behaviours and beliefs based on early corporate successes' [122,

p114]. This is advantageous because core capabilities are not easily copied, however there is a downside:

*“Values, skills, managerial systems, and technical systems that served the company well in the past and may still be wholly appropriate for some projects or parts of projects, are experienced by others as core rigidities – inappropriate sets of knowledge.” [122, p118]*

The unique collection of competences (and rigidities) a firm possesses directly affects its attitudes to whether and how it acquires new technologies. Tidd & Bessant [4, p472] and Tidd & Trewhella [124] highlight the importance that this ‘organisational inheritance’ has in decision-making relating to technology acquisition – existing capabilities, know-how and management’s receptivity to external knowledge combine to influence the outcome.

External technology acquisition to develop core competence and agility is not a quick fix. It doesn’t necessarily add to core competence in the short term – initially it is just a means to access skills. It should be considered as an ‘asset acquisition’ initially because it takes a significant amount of management effort to nurture and embed it before it can be thought of as a core capability [123, p155].

Tidd & Trewhella [124] argue that for an acquired technology to translate into an embedded competence the firm must treat the acquisition not just as an opportunity to reduce its operating costs but as an *opportunity to learn*.

The ability of managers to build, integrate and ultimately reconfigure competencies and resources is fundamental to the successful exploitation of existing skills and the development of new ones [4, p205]. This necessary attribute of organisations is a *dynamic capability*.

## 2.3.2 Dynamic Capabilities

Although the resource-based view of the firm has been deemed a valid construct, it was considered insufficient when dealing with rapidly changing markets where ‘*a dominant focus on core resources may create rigidities that prevent firms from adapting their resources to the new competitive environment*’ [65, p5]. This was addressed by Teece et al [91] in 1997 with their introduction of the concept of ‘dynamic capabilities’.

Newey & Zahra [125] distinguish between operating and dynamic capabilities. Operating capabilities enable a business to undertake its core activities – e.g. design, production, sales – and as such tend to be routine procedures. However in dynamic environments these procedures can be a source of inertia or rigidity.

Benner [126] suggests that the rise of ISO9000 quality procedures, TQM and lean manufacturing principles – while beneficial when considered in isolation – can emphasise the routinisation of operating capabilities to the point where innovation is severely restricted.

*“Dynamic capabilities counter this effect and are defined as the ability of the firm to reconfigure operating capabilities and thus allow the organization to adapt and evolve.”* [125, pS81]

Eisenhardt & Martin [127], Ellonen et al [128] and Helfat & Winter [129] contend that dynamic capabilities are required to transform operational capabilities to meet the demands of a changing environment.

*“Sometimes it is effective to use these [dynamic capability] tools to enhance existing resource configurations and to strengthen the current position ... More frequently, in dynamic markets, it makes sense to use dynamic capabilities to build new resource configurations”* [127, p1118]

The positive correlation between dynamic capabilities and firm performance in the context of turbulent environments has been confirmed by multiple studies, for example Fainshmidt [130]. In 2009 Teece [119] amplified the definition of dynamic capabilities;

*“The ability to **sense** and then **seize** new opportunities, and to **reconfigure** and protect knowledge assets, competencies and complementary assets so as to achieve sustained competitive advantage.”* [119, p206]



Dynamic capabilities are therefore formed of three elements, sensing, seizing and reconfiguring. **Sensing** involves scanning across technologies and markets, both local and distant. There is a need to embed the scanning in the business and not to leave it to a few individuals. This has parallels with *periphery scanning* discussed in section 2.2.5 in connection with the development of corporate strategy.

New product development is an example of **seizing** the sensed opportunities. Teece comments on the importance of staying flexible until the dominant design emerges and then investing heavily. Maintaining competitiveness is achieved by managing threats and **reconfiguring**.

*“... reconfiguration is needed to maintain evolutionary fitness and, if necessary, to try to escape from unfavourable path dependencies.”* [119, p34]

Managerial capabilities play a key role in this process. Teece 2012 [120] highlights the importance of leadership skills to effect the reconfiguration of resources.

*“... top management’s entrepreneurial and leadership skills around sensing, seizing, and transforming are required to sustain dynamic capabilities. Put differently, an important managerial function – perhaps the most important – is to achieve semi-continuous asset orchestration and renewal, including the redesign of routines.”* [120, p1398]

Kor & Mesko [131] and Helfat & Martin [132] look specifically at dynamic *managerial* capabilities, their antecedents of cognition, social capital and human capital and how these are used to reconfigure – or orchestrate – firm capabilities and resources.

### 2.3.3 Asset & Resource Orchestration

Thomke & Kuemmerle [133] identify the importance of valuable, rare and inimitable asset accumulation, and this is restated by Teece [134] and Camisón & Villar López [135] who both emphasise the temporary nature of asset value. Assets depreciate in technological terms and not just by financial accounting principle.

*“The erosion of asset value does not only stem from competitors’ attempts to imitate, but also from the success of the substitution processes that*

*enable the generation of strategically equivalent assets. Innovation is the only way in which the firm can protect itself against the risk of devaluation, and work to ensure that the superiority of its assets remains a permanent feature.” [135, p856]*

So continuous asset development and reconfiguration through innovation activity is important to ensure long term competitiveness.

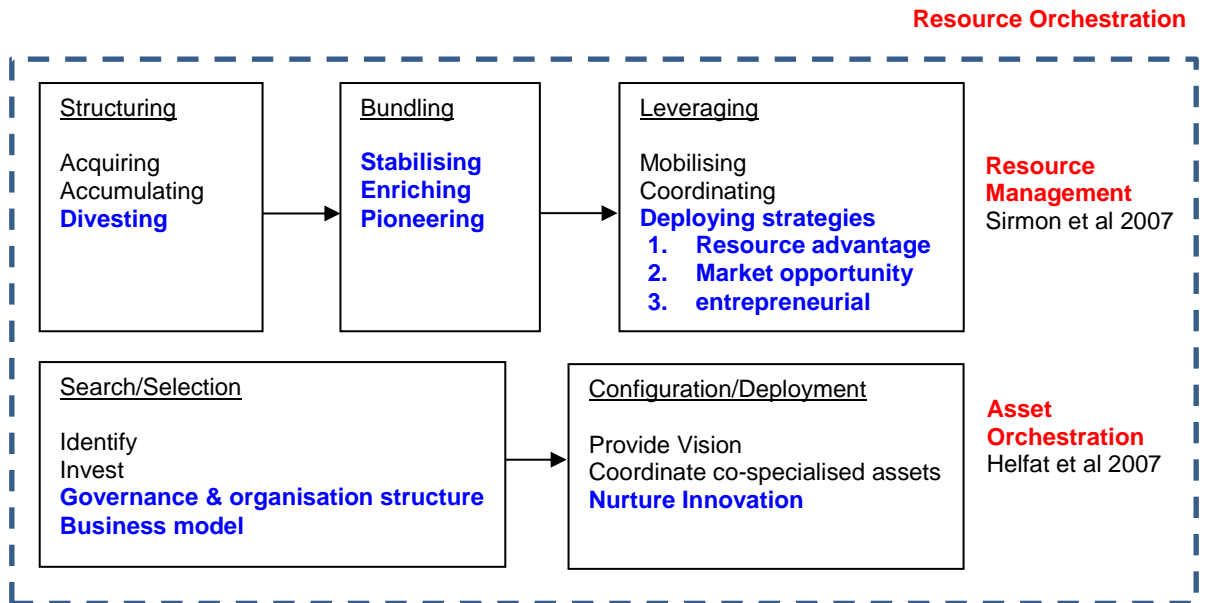
Sirmon et al [136] & Sirmon & Hitt [137] study this ‘under-researched’ area (as they deem it) of managerial ‘resource management’– their term for the last stage in Teece’s three stage dynamic capability construct – sense, seize, reconfigure. Sirmon et al break down resource management into two elements – resource investment and resource deployment. Alignment between investment and deployment is critical for optimal performance and that over-investing in physical or human resources can be detrimental.

At the same time Sirmon et al were examining ‘resource management’, Helfat et al presented their ‘asset orchestration’ construct [138]. This is subtly different, but is again broken down into two elements: *Search & Selection* and *Configuration & Deployment* [138, p28]:

*“Rather than stressing opportunism ... the emphasis in dynamic capabilities is on change processes, inventing and reinventing the architecture of the business, asset selection, and asset orchestration,” [138, p28]*

*“Such managerial activity involves, inter alia, orchestrating complementary and co-specialised assets, inventing and implementing new business models, and making astute investment choices ... in situations of uncertainty and ambiguity.” [138, p25]*

Sirmon et al [139] subsequently combined his own ‘resource management’ framework and Helfat’s ‘asset orchestration’ framework into a new construct – ‘resource orchestration’. This is pictorially represented in figure 7. Resource management focuses on structuring the portfolio, bundling to create capabilities and leveraging capabilities in the market place, whereas asset orchestration focuses on search/selection and configuration/deployment. So Sirmon et al contend that the two are complementary, and that items in bold blue in figure 7 have no conceptual equivalent in the other framework.



**Figure 7 – Resource Orchestration Framework**  
(Sirmon et al 2011 [139, p1395])

Li et al [140] make the link between effective resource orchestration and the ultimate strategic flexibility of the organisation to respond to environmental turbulence – an idea that will be returned to in section 2.3.8.

Sirmon [139] and Lin et al [141] argue that successful resource orchestration relies on effective knowledge management

*“Exploration requires structuring processes that acquire and accumulate new sources of knowledge that contribute to the development of new innovations. It also necessitates efforts to integrate this knowledge into the firm’s operations, and the bundling of resources to create capabilities that enrich existing products and technologies and hopefully also enable the firm to pioneer products for new markets.” [139, p1402]*

The firm’s ability to identify, assimilate and apply new knowledge is known as its ‘absorptive capacity’.

### 2.3.4 Absorptive Capacity

Emerging from the discussion on dynamic capabilities is the importance of building capabilities through organisational and individual knowledge. The path dependency of dynamic capabilities underlines the fact that they are developed over time and not bought (Ambrosini et al [142, pS11]);

*“Competences and capabilities are intriguing assets as they typically must be built because they cannot be bought.”* [91, p518]

*“The difficult resource to accumulate is knowledge. Knowledge is harder to monitor and manage than is financial capital. In an open economy with rapid technological change, the challenge is less about managing financial resources and more about managing, learning, knowledge accumulation and protection.”* [119, pp211-2]

Zollo & Winter [143] describe how dynamic capabilities are learned through experience accumulation, knowledge articulation and codification. Barrales-Molina et al [144] examine these mechanisms and the effect environmental dynamism has on their efficacy. Their conclusions, which are supported by Macher & Mowery [145], emphasise the importance of the deliberate rather than passive learning processes for the development of dynamic capabilities.

A firm's ability to accumulate and exploit knowledge has been termed its 'absorptive capacity'. The initial absorptive capacity construct was developed by Cohen & Levinthal [146-148]. They proposed that the long run cost of learning is substantial and that this cost is borne via the development of a stock of prior knowledge.

*“The premise of the notion of absorptive capacity is that the organization needs prior related knowledge to assimilate and use new knowledge.”* [147, p129]

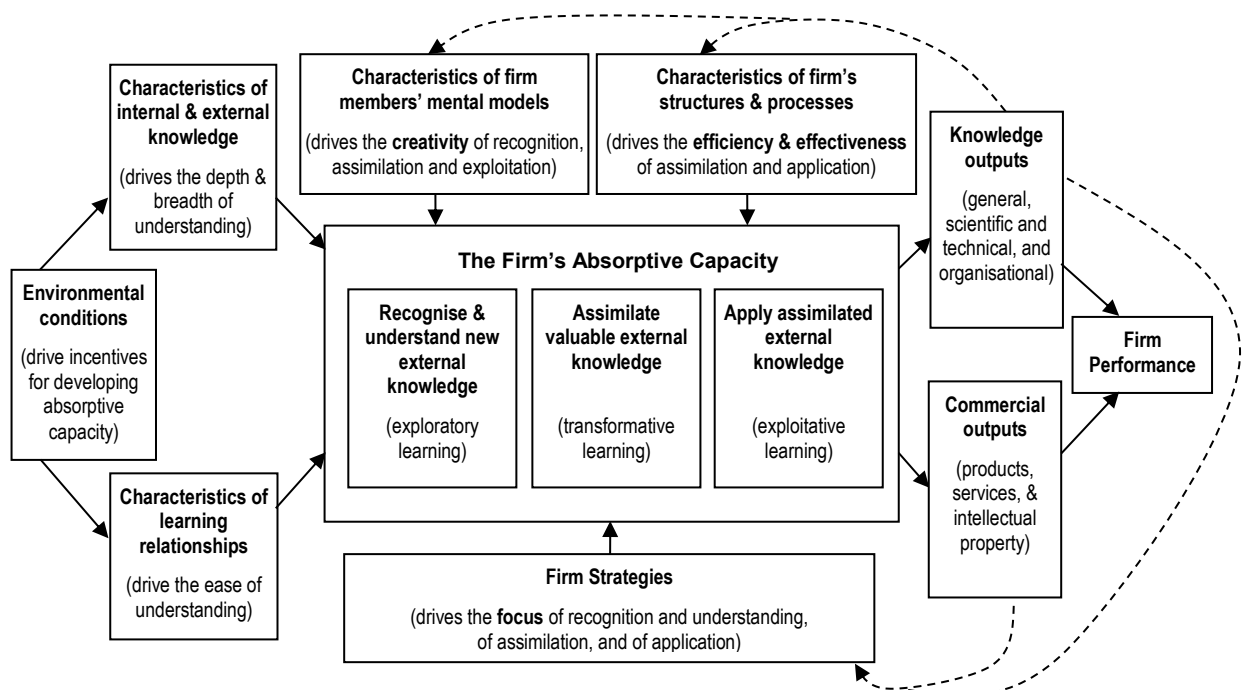
Cohen & Levinthal state that absorptive capacity can be developed not only through R&D activities but also through manufacturing experience (i.e. learning by doing) and formal training. Absorptive capacity is likely to accrue in this manner when the area that the firm wishes to exploit is linked or adjacent to its existing expertise. In a similar fashion to core competences it is difficult just to 'buy-in' absorptive capacity.

*“Acquiring general technical knowledge through market exchange is often not sufficient because an effective absorptive capacity requires that the same individuals possess both this general technical knowledge and the knowledge of the firm's idiosyncratic needs.” [148, p237]*

Absorptive capacity improves the firm’s ability to envisage future technical advances as well as being able to exploit them. It is cumulative by nature – ‘building on what’s gone before’ – i.e. path dependent. The ability to evaluate discontinuous situations is impossible without absorptive capacity in that new field.

*“A firm without a prior technological base in a particular field may not be able to acquire one readily if absorptive capacity is cumulative. In addition ... firms may not realize that they should be developing their absorptive capacity ... the firm needs to have some absorptive capacity already to value it appropriately.” [147, p138]*

Lane et al [149] graphically represented Cohen & Levinthal’s concepts and this is shown in figure 8.



**Figure 8 – A Process Model of Absorptive Capacity**  
(Lane et al [149, p856])

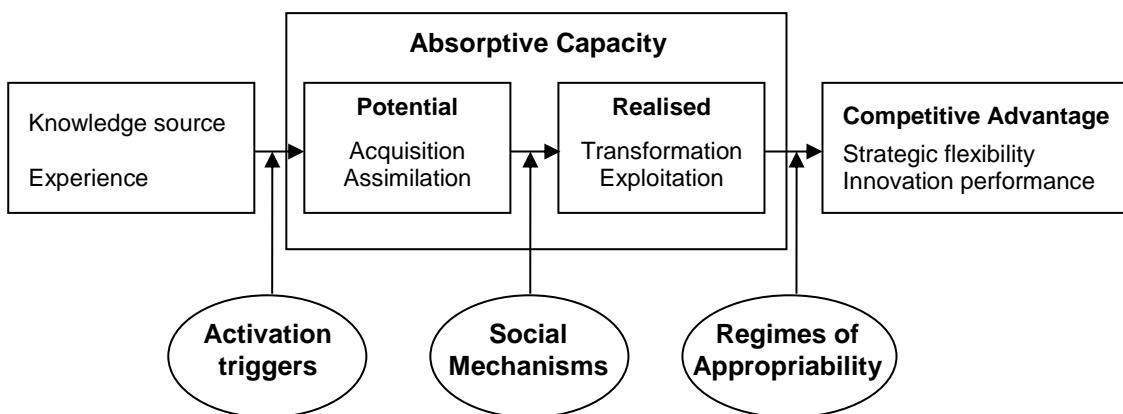
Lichtenthaler [150] examines the three learning categories from Cohen & Levinthal – exploratory learning, transformative learning and exploitative learning. He shows that the positive effect of all three learning types are enhanced by market and technological turbulence and that a balance of the three types is beneficial. Transformative learning is related to knowledge retention over time. Unless this is actively managed in order to keep assimilated knowledge ‘alive’, skills and competence will be gradually lost to the business [150, p825].

Zahra & George [151] consider absorptive capacity to be a dynamic capability and define it as

*“... as a set of organizational routines and processes by which firms acquire, assimilate, transform, and exploit knowledge to produce a dynamic organizational capability.”* [151, p186]

So they extend Cohen & Levinthal’s three element concept into four elements. These are then organised into two sub-groups: *Potential Absorptive Capacity* – acquisition and assimilation, and *Realised Absorptive Capacity* – transformation and exploitation.

Zahra & George’s model of absorptive capacity is shown in figure 9.



**Figure 9 – A Model of Absorptive Capacity**  
(Zahra & George [151, p192])

Organisations with different relative levels of potential and realised absorptive capacity are likely to sustain competitive advantage in different ways;

*“Firms with well-developed capabilities of knowledge acquisition and assimilation [Potential Absorptive Capacity] are more likely to sustain a competitive advantage because of greater flexibility in reconfiguring their*

*resource bases and in effectively timing capability deployment at lower costs than those with less developed capabilities.” [151, p196]*

*“Firms with well-developed capabilities of knowledge transformation and exploitation [Realised Absorptive Capacity] are more likely to achieve a competitive advantage through innovation and product development than those with less developed capabilities.” [151, p196]*

Cepeda-Carrion et al build on Zahra & George’s work contending that potential absorptive capacity *‘requires change, flexibility and creativity’* of the organisation’s structure and culture, whereas realised absorptive capacity *‘requires order, control and stability’* [152, p111]. Patel et al expand on this by suggesting that greater potential absorptive capacity *‘allows firms to more fully explore the peripheries of innovation possibilities’*, while greater realised absorptive capacity increases *‘the likelihood of exploiting potentially valuable innovations’* [153, pp1741-2].

It is unsurprising that the level of absorptive capacity is linked to innovation performance – however this is much more readily demonstrated by the literature for incremental innovation than radical innovation, for example Su et al [154]. However, Zhou & Wu [155] do demonstrate that an increased level of absorptive capacity results in more explorative innovation and Hoang & Rothaermel [156] show that the presence of internal exploratory expertise facilitates the use of external innovation partners.

Weigelt counsels caution when firms attempt to make use of external expertise. Outsourcing is useful to avoid internal competence rigidities, but can lead to a reduction in internal capabilities by not following learning-by-doing trajectories [157, pp597-8]. Higher degrees of outsourcing progressively reduce the firm’s ability to assimilate the associated competences of the outsourced technologies.

*“... greater vertical integration is superior to outsourcing of business process enhancing technologies. These findings are consistent with RBV ... arguments that state that greater vertical integration is preferred for interdependent activities involving tacit knowledge. Given a common language and shared understanding among employees, vertical integration is superior for the coordination of tacit, context-specific know-how” [157, p610]*

Parmigiani & Mitchell [158] seek to address the danger of excess outsourcing by recommending 'concurrent sourcing' internally and externally rather than simple 'make-buy' alternatives. They recognise that even though internal production is a means of organisational learning (learning-by-doing) that excessive outsourcing can jeopardise, firms can augment this internal knowledge acquisition by selectively outsourcing. The external knowledge that is assimilated in this way enables the firm to improve the effectiveness of their own production processes.

*"... firms benefit from the broad and diverse types of knowledge they acquire through supply relationships, because this learning augments knowledge that the firm obtains through internal production and provides the firm with a greater degree of absorptive capacity."* [158, p1083]

Zhang et al [159] agree that this balance of internal and external knowledge acquisition is beneficial and observe that the virtuous knowledge cycle – a firm's prior knowledge leading to a greater ability to assimilate external knowledge providing the springboard for further internal process improvements – leads to a general improvement in manufacturing flexibility.

Absorptive capacity is a key dynamic capability that both enables and constrains organisations' ability to reconfigure their assets, resources and capabilities to meet the challenges posed by dynamic market and technological environments. The ability to exploit previously acquired and assimilated knowledge requires that organisations manage that stock of knowledge effectively and this is discussed in the next section.

### 2.3.5 Knowledge Management Frameworks

In addition to absorptive capacity – the importing and absorbing of **external** technological knowledge – Leonard-Barton contends that there are three other more internally focused knowledge-creating activities, or 'knowledge flows', that ultimately create and control the knowledge necessary for an organisation's current and future operations [123, p8]:

- Shared, creative problem solving in order to produce current products.
- Implementing and integrating new methodologies and tools to enhance internal operations.
- Formal and informal experimentation to build capabilities for the future.



These four knowledge-creating activities build and shape the four interdependent dimensions of a firm's technological capability [123, p19]:

- Physical technical systems (equipment, software, databases etc).
- Employee knowledge and skill.
- Managerial systems which guide the accumulation of employee knowledge through structured education, rewards and incentives.
- Values and norms of senior management and influential peers determine what kinds of knowledge and knowledge-building activities are tolerated and encouraged.

Of these four dimensions '*we can readily see the accretion of physical systems*', while the other three are much less visible or tangible [123, p27]. There is also an increasing resistance to change moving down this list, i.e. physical systems offer least resistance to change and business values are most resistant [123, p45]. An organisation's unique and often inimitable combination of these four elements is where sustained competitive advantage can be found [123, p20]

Leonard-Barton's framework of knowledge-creating activities building technological capability has been built on by subsequent authors leading to Tranfield et al's [30] nuanced definition of knowledge management:

*"... the process by which the capacity to act is facilitated or enhanced, matching knowledge sources to knowledge needs, using performative competencies which privilege the flow and sharing of knowledge over simple custody, and which is value rated by its contextual efficacy"* [30, p46].

Knowledge sources exist in two main forms: *explicit* and *tacit* [5, p150]. Explicit knowledge is formal and systematic. It can be codified – or documented – in an easily understood manner, for example in instruction manuals, textbooks or standard operating procedures. Tacit knowledge is more difficult to capture because it is based on individuals' expertise, built up over time, and which the individuals themselves often find hard to articulate.

The ease of codification of explicit knowledge results in it being more readily stored, typically in company databases and computer systems. Articulation and codification of tacit knowledge is also very important, but more difficult and time-consuming to

achieve. Mechanisms such as *socialisation* and *externalisation* are respectively used to articulate and codify tacit knowledge [5, p152]. Socialisation encourages tacit to tacit knowledge articulation and transfer by creating an environment where less experienced employees 'shadow', observe and learn from their more experienced colleagues. Externalisation describes the process of finding ways to convert tacit to explicit knowledge, which may require developing unique methods to codify this specialised knowledge [52, p1010].

Tidd & Trewhella contend that tacit knowledge that is difficult to codify, is also, by definition, more difficult to acquire from outside of the business because it '*can only be transferred effectively by 'face-to-face' interactions*' [124, p372]. They conclude that technologies reliant on a high degree of tacit knowledge should be developed from within the organisation because they provide a more durable source of competitive advantage.

Acquiring and codifying knowledge must be followed by the *dissemination* and *retention* of that knowledge for organisational learning to have successfully taken place [124, p374]. Cepeda-Carrion et al observe that organisations' information systems are key repositories that provide a route to '*classifying and providing access to what has already been learned and successfully applied*' [152, p114].

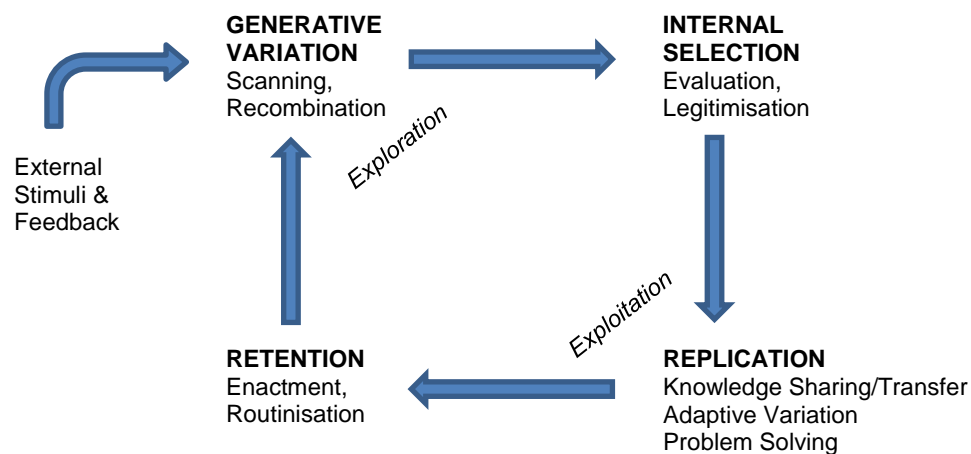
*"... the [information system] capability should allow companies to incorporate knowledge into their systems through a codification process, to complete or substitute this knowledge with past experiences and to make it available to any member of the company. It is the use of this capability that governs how the useful new knowledge is applied for developing innovations."* [152, p124]

Potentially useful, but perhaps not immediately deployed, assimilated knowledge can gradually wither over time if it is not kept 'alive' [150, p825]. The retention of hard-won knowledge acquisition can be achieved by its deliberate 'reactivation' through regular review, discussion and experimentation.

Zollo & Winter [143] propose a framework that draws together these stages of knowledge evolution – acquisition, assimilation, dissemination and retention. This is shown in figure 10.

The launching point of the cycle is in the variation stage where solutions are sought to challenges facing the organisation. Solutions are generated by combining external

stimuli such as competitors' initiatives and scientific discoveries, with information already existing in the firm. Ideas arising from this explorative activity are then subject to selection pressures as they are evaluated for their potential to enhance existing routines or develop new ones. Once adopted, selected ideas are diffused through the organisation to those individuals required to adopt them. This replication phase not only exploits the new knowledge by distributing it to where it is required, it also adds diversity to the firm's stock of knowledge that contributes to subsequent variation phases of new knowledge cycles. The final stage in the cycle is the embedding and retention of the new routines in the business through repetition [143, p344].



**Figure 10 – Activities in the Knowledge Evolution Cycle**  
Zollo & Winter [143, p343]

The first two phases of Zollo & Winter's knowledge evolution cycle result in two distinct forms of new knowledge – knowledge that is selected for immediate use and knowledge that is not. Zollo & Winter focus on the former and how it is subsequently exploited and retained. Knowledge that is acquired but not immediately used is also important because, if it can be effectively categorised and retained, it provides a pre-existing knowledge landscape for future information searches. This is reflected in the preliminary stages of innovation management frameworks.

Tranfield et al's [30] work developing their DRN – 'discovery-realisation-nurture' – innovation management framework (previously mentioned in section 2.2.3) analyse real-world examples of knowledge management activities in each of their model's phases. These are shown in figure 11.

Innovation Phase	Routines	Description	Knowledge Management Activities
Discovery	Search	The passive and active means by which potential knowledge sources are scanned for items of interest	Active environmental scanning (technological, market, social, political) Active future scanning Experiment — R&D, etc.
	Capture	The means by which knowledge search outcomes are internalised within the organisation	Picking up relevant signals and communicating them within and across the organisation to relevant players
	Articulate	The means by which captured knowledge is given clear expression	Concept definition Strategic and operational planning cycles
Realisation	Contextualise	The means by which articulated knowledge is placed in particular organisational contexts	Resource planning and procurement Prototyping Early mobilisation across functions — design for manufacture, quality
	Apply	The means by which contextualised knowledge is applied to organisational challenges	Project team mobilisation Project planning cycles Project implementation and modification Launch preparation and execution
Nurture	Evaluate	The means by which the efficacy of knowledge applications is assessed	Post-project review Market/user feedback Learning by using & making etc.
	Support	The means by which knowledge applications are sustained over time	Feedback collection Incremental problem-solving and debugging
	Re-innovate	The means by which knowledge and experience are re-applied elsewhere within the firm	Pick up relevant signals to repeat the cycle Mobilise momentum for new cycle

**Figure 11 – DRN Knowledge Management Activities**  
Tranfield et al [30, p45]

The first phase in particular – *discovery* – emphasises the need to thoroughly map out the relevant knowledge landscape before making innovation selections. It can be seen from figure 11 that there are parallels between Tranfield et al’s innovation framework’s phases of discovery, realisation and nurture and Zollo & Winter’s knowledge evolution cycle phases of variation/selection, replication and retention respectively. Knowledge management phases seen in innovation management frameworks are also reflected in product development models because product development teams employ existing knowledge and create new knowledge in the pursuit of realising innovative products [160, p68].

Katz’s [37] new product development model, for example, has ‘discovery’ as its first stage which comprises exploratory research, review of secondary online sources, ethnography and tapping into online communities [37, p28]. Practical application of structured knowledge management activities in a product development environment is exemplified at Rolls Royce where the particular framework stages are labelled [161, p36]:

- Identification & Monitoring (generative variation)
- Selection & Approval (internal selection)
- Capability Development (replication)
- Protection (retention)

Petrick & Martinelli [87] in their work on strategic road mapping argue that such ‘discovery’ phases are crucial in anticipating future trends, the knowledge of which allows leaders to plan technology investments earlier than would otherwise have been the case [87, p55].

The management of knowledge, both explicit and tacit, is critical to organisations’ ability to execute innovative programmes, to develop new products and to deploy technology investments. Literature reviewed in this section has identified knowledge management activities associated with innovation management frameworks and new product development models. Such activities are important to both develop a broad view of the technological landscape, as well as to create knowledge for specific product developments.

It has been shown over the last five sections, how a resource-based view of strategy is an important counterbalance to the more traditional outward-looking competitive forces approach to strategy development. Dynamic capabilities – as distinct from the routine operating capabilities all organisations need to function – are required to reconfigure and orchestrate assets and resources to maintain the business’ competitive position in turbulent environments. Key amongst these dynamic capabilities is the ability to recognise, assimilate, manage and apply new knowledge. The next section looks at the context within which these asset and resource orchestrations take place – the organisation’s manufacturing strategy.

### 2.3.6 Manufacturing Strategy

According to Hayes & Wheelwright manufacturing strategy is concerned with assembling a set of capabilities that ensures that the firm can deliver its long term business strategy [162, p33]

Hayes & Wheelwright suggested that manufacturing strategy had been neglected and had played a subservient role to traditional business strategy development processes:

*“Too often companies have acted as if they were driven by market and competitive forces alone, and as if manufacturing’s role was simply to respond to those forces by enlisting and coordinating the adjustments and resources provided by suppliers of parts and equipment.”* [162, p21]

Hill [163] agrees with this view, observing that operations units have for too long been concerned only with efficiency and output capacity. Indeed, in Liao et al’s [164] recent review of the state of the ‘fourth industrial revolution’ – *Industry 4.0* – resource productivity and efficiency features as a priority area for action, whereas there is little mention of innovation, competitive capabilities or manufacturing’s potential contribution to business strategy. Taking such a reactive role offers little or no strategic contribution [163, p25]. Hayes & Wheelwright contend that manufacturing should not be seen as a reactive force, but should be seen as having the capability to be a competitive weapon, *‘rather than just a collection of rather ponderous resources and constraints’* [162, p35].

Hayes & Pisano [165] argue that the introduction and application of Porter’s competitive strategy framework [90] in the 1980’s created a

*“... sharper demarcation between the domains of competitive strategy and manufacturing strategy than had existed before ... Whereas the roots of Porter’s framework were in industrial organisation economics and were based on industry-level studies, the manufacturing strategy framework was based on the specific nature of manufacturing and technology at the firm level.”* [165, p30]

This separation between competitive strategy and manufacturing strategy has led to a disconnect between the two literature areas. Brown & Blackmon [8] observe:

*“... manufacturing has increasingly lost touch with the mainstream corporate and business strategy literature ... Environmental and other*

*changes have caused manufacturing strategy to drift away from the strategy mainstream, particularly the market-led and resource-driven approaches to strategy. However, manufacturing must be aligned with corporate strategy in order to contribute to performance.” [8, p794]*

While it is recognised that manufacturing must be aligned with corporate strategy, firms should not fall into the trap of thinking that this implies manufacturing must ‘follow’ corporate strategy or react to it. Manufacturing has more potential than just being a subservient partner in strategy development.

### 2.3.6.1 Manufacturing’s Contribution & Alignment with Business Strategy

Hayes & Wheelwright present a four stage model of manufacturing’s competitive potential (or maturity) – shown in table 5. They argued that the goal for operations units should be to move towards stage 4 so that not only can they participate in strategy formulation, they can even instigate strategy changes.

**Table 5 – Stages of Manufacturing’s Competitive Potential**  
Hayes & Wheelwright [162, p396]

<p><b>Stage 1</b> – Minimise Manufacturing’s Negative Potential: <b>‘Internally Neutral’</b></p> <ul style="list-style-type: none"> <li>• External experts are used in making decisions about strategic manufacturing issues.</li> <li>• Internal management control systems are the primary means for monitoring manufacturing performance.</li> <li>• Manufacturing is kept flexible and reactive.</li> </ul>
<p><b>Stage 2</b> – Achieve Parity with Competitors: <b>‘Externally Neutral’</b></p> <ul style="list-style-type: none"> <li>• ‘Industry Practice’ is followed</li> <li>• The planning horizon for manufacturing investment decisions is extended to incorporate a single business cycle.</li> <li>• Capital investment is regarded as the primary means for catching up to competitors or achieving a competitive edge</li> </ul>
<p><b>Stage 3</b> – Provide Credible Support to the Business Strategy: <b>‘Internally Supportive’</b></p> <ul style="list-style-type: none"> <li>• Manufacturing investments are screened for consistency with the business strategy.</li> <li>• Changes in business strategy are automatically translated into manufacturing implications.</li> <li>• Longer-term manufacturing developments and trends are systematically addressed.</li> </ul>
<p><b>Stage 4</b> – Pursue a Manufacturing-Based Competitive Advantage: <b>‘Externally Supportive’</b></p> <ul style="list-style-type: none"> <li>• Efforts are made to anticipate the potential of new manufacturing practices and technologies.</li> <li>• Manufacturing is centrally involved in major marketing and engineering decisions</li> <li>• Long range programmes are pursued in order to acquire capabilities in advance of needs.</li> </ul>

The seminal strategy development process proposed by Hill in 1985 [163] (and subsequently re-emphasised by Berry et al [166] and by Hill & Hill [167]) seeks to ensure full involvement of the manufacturing function in the development of a firm's corporate strategy and hence position the organisation at a maturity level 3 or 4. Hill's process is represented in figure 12.

1	2	3	4	5
Corporate Objectives	Marketing Strategy	How do products win orders in the market place?	Manufacturing Strategy	
			Process Choice	Infrastructure
<ul style="list-style-type: none"> <li>• Growth</li> <li>• Profit</li> <li>• ROI</li> <li>• Other financial measures</li> </ul>	<ul style="list-style-type: none"> <li>• Product markets/ segments</li> <li>• range</li> <li>• mix</li> <li>• volumes</li> <li>• standardisation vs customisation</li> <li>• level of innovation</li> <li>• leader vs follower alternatives</li> </ul>	<ul style="list-style-type: none"> <li>• Price</li> <li>• Quality</li> <li>• Delivery speed/ reliability</li> <li>• Colour range</li> <li>• Product range</li> <li>• Design leadership</li> </ul>	<ul style="list-style-type: none"> <li>• Choice of alternative processes</li> <li>• Trade-offs embodied in process choice</li> <li>• Role of inventory in the process configuration</li> </ul>	<ul style="list-style-type: none"> <li>• Function support</li> <li>• Manufacturing systems</li> <li>• Controls &amp; procedures</li> <li>• Work structuring</li> <li>• Organisational structure</li> </ul>

**Figure 12 – Manufacturing Strategy Framework**  
Hill [163, p41]

The first three steps are somewhat sequential and deterministic in Hill's view, and are not dissimilar to other more standard strategy texts. The key difference is the iterative nature of steps 3, 4 and 5 where manufacturing's contribution to the order winning abilities of the product range is closely considered. These steps are entirely absent from standard strategic management texts.

Hill suggests that the outcome of this strategy development process is that the size and nature of the gap between the marketing strategy and what the manufacturing infrastructure and capabilities can deliver is clearly identified. The organisation can then decide how to address the gap to ensure maximum alignment of marketing and manufacturing strategies. Hill cautions against losing this alignment over time as marketing-led strategies incrementally shift the focus of the task required by manufacturing.

Hill asserts that alignment is achieved and maintained by developing manufacturing infrastructure which consists not just of physical assets but also controls, procedures and systems [163, p160]. It is such a sequence of decisions and actions designed to achieve a set of manufacturing capabilities that constitute a business' manufacturing strategy.



So there are links here to building and reconfiguring operational capabilities which chime with the RBV and Dynamic Capability literature although Hill does not use those terms. Hill also recognises that by selecting particular configurations of infrastructure, limits are placed on the degree of agility and flexibility to change in the future. Process positioning...

*“... restrict[s] a company’s ability to change direction in the future due to earlier integration moves, often justified on the short-term rationale of profit return.” [163, p141]*

So here Hill is reflecting Teece’s concept of technological trajectories discussed in section 2.3.1 – but again without using Teece’s terminology.

In spite of Hill’s exhortation for manufacturing to be integral to the strategy setting process, there remains in his framework the principle that manufacturing is set a task and then develops capabilities and capacities to achieve it – a reactive position.

Spring & Boaden [168] agree that Hill’s approach is only part of the picture:

*“... approaches such as Hill’s that so strongly emphasize the product/market dimensions offer only a limited view of what manufacturing strategy could be.” [168, p774]*

Hayes & Pisano [165] and Dangayach & Deshmukh [169] argue there is a gradual shift towards an RBV and Dynamic Capabilities approach.

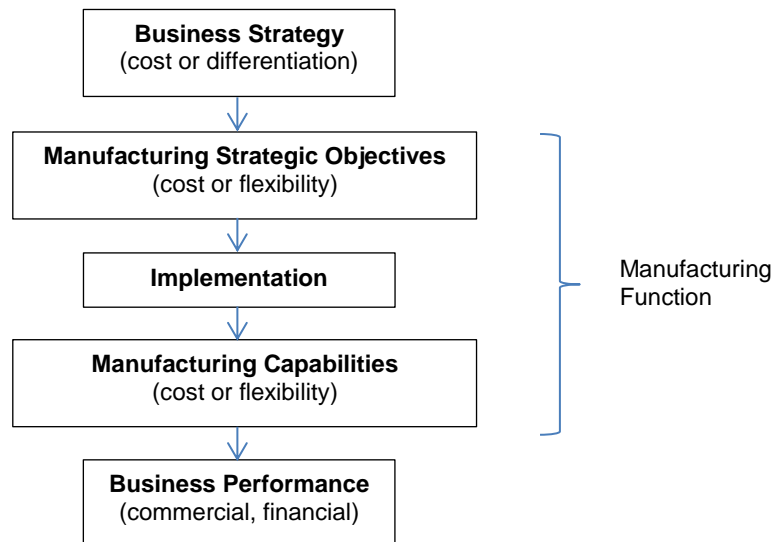
*“Operation strategy is gradually moving from a market-based to a resource-based view (RBV) of competition. Earlier, operations were seen as a perfectly adjustable system focused to follow the rules dictated by markets successfully, while RBV suggest that it is more profitable to focus on developing, protecting, and leveraging a firm’s unique operational resources ... This paradigm shift started with evidence that high performance is explained primarily by the strength of a firm’s resources, and not by the strength of its market position.” [169, p914]*

However the RBV approach is not universally applied. Focus remains significantly on alignment of the manufacturing task with driving corporate objectives. This is evident in numerous articles; for example Williams et al [170], Gupta & Lonial [171] and Ward & Duray [172]. In all cases the manufacturing strategy is subservient to the business

strategy. In 2010 González-Benito & Suárez-González [9] presented the predominant model of manufacturing strategic planning. This is shown in figure 13.

*“Although authors such as T. J. Hill (1985) have proposed refinements to this framework, such as by explicitly introducing marketing requirements, the essence remains basically the same: there must be an alignment between the manufacturing function and the business strategy.” [9, p1029]*

So it is interesting that in the 25 years between Hill in 1985 and González-Benito & Suárez-González in 2010 the same linear, deterministic model of manufacturing strategy development is seen as ‘predominant’.



**Figure 13 – Predominant Model of Manufacturing Strategic Planning Process**  
(González-Benito & Suárez-González [9, p1029])

As recently as 2014 González-Benito & Lannelongue repeat the contention that manufacturing strategy plays a reactive role – ‘*The formulation of strategy also mainly appears as a top-down, outside-in, or market-led process*’ [173, p1129].

Indeed the focus of operations management research papers between 2004 and 2009 has been found to be in the area of supply chain management rather than challenging the strategy development process (Taylor & Taylor [174]).

A key element of manufacturing strategy is the approach to investing in new technology. An organisation’s manufacturing technology strategy is discussed in the next section.

### 2.3.6.2 Manufacturing Technology Strategy

As a means to develop manufacturing capabilities – either to create better alignment between manufacturing and business strategy, or to allow operations to stimulate original strategy – the technology strategy of operations units has received some attention in terms of processes to guide selection, acquisition and outsourcing.

Hayes & Wheelwright [162] observe that top management teams are increasingly non-technical which drives the company to externally source manufacturing technology and to hire in supporting expertise. Hayes & Wheelwright contend that this reflects an assumption that technology is easily tradable.

*“Such activities ultimately destroy both a company’s willingness and its capabilities to develop its own proprietary technology, and thus use technology as a competitive weapon. Technological capability is not something that can be bought and sold easily. If it were it would not constitute an enduring competitive advantage. It is not an object it is an objective; something that one must seek and perfect continuously or it will erode.”* [162, p332]

Similarly top management’s lack of technology planning can compromise new product development processes. Terry Hill, in an interview with Steve Brown, suggests:

*“Companies do not invest based on following a process life cycle or part of a process life cycle. They only intend (and often can only justify) investing the one time once a product is launched commercially.”* [175, p378]

Meredith & Vineyard conclude, surprisingly, that even the *image* that a technological acquisition can create plays a part in the investment decision.

*“... the concept of "image" as a competitive priority for manufacturing may sound heretical for operations managers and academicians but it is apparently important to firms and is commonly the basis for their manufacturing strategy.”* [176, p22]

There are examples of manufacturing-based technology management processes in the literature (e.g. Foden & Berends [161] – the technology identification, selection, development, acquisition, exploitation and protection process at Rolls Royce), however

these are limited in their view of the wider impact on the competitive position the manufacturing technology engenders, and are also limited in their view of the longer term flexibility that may be created.

Organisations can choose to acquire and develop their own proprietary technologies or to work closely with supply chain partners who may be better placed to provide dedicated technologies for the organisation's use. Autry et al [177] find that a firm's propensity to adopt technology depends on the organisation's absorptive capacity and the degree of separation between existing and proposed technologies – or, in other words, the degree of 'reach' the organisation must make to deploy the new technology.

Jin et al [178] examine more closely a firm's proprietary technologies and suppliers' dedicated technologies and their impact on firm performance. Their conclusions are that proprietary technologies positively impact a firm's competitive advantage as measured by quality, delivery and time-to-market, and that suppliers' dedicated technologies positively impact a firm's flexibility.

*“... neither proprietary technologies nor suppliers' dedicated technologies are a panacea to building sustainable competitive advantage ... It is important to balance the investment in technologies inside and outside of a firm to achieve the best overall performance ... because proprietary technologies and suppliers' dedicated technologies build different competitive advantage.” [178, p5722]*

This argument runs parallel, and is consistent with, the need to balance the internal and external sources of knowledge as discussed in section 2.3.4 in relation to absorptive capacity.

A firm's process technology should evolve in a deliberate fashion so that the organisation's longer term competitive position is optimised [162, p195]. The ability to take a longer term view is often compromised by accounting perspectives. Research into decision-making models for asset replacement shows that they typically do not take into account capabilities that may be introduced or extended by the new asset (see for example Yatsenko & Hritonenko [179]). Common accounting metrics such as Return on Investment (ROI) focus entirely on the direct effects of production efficiency, with little attention being paid to the *change in competitive position* that the investment unlocks – this is rarely accounted for in investment evaluations – *'excessive use of ROI distorts strategy-building'* [163, p205].

Hayes & Pisano [180] argue that investment should be seen as 'capability building':

*"Rarely, if ever, is a strategically worthwhile capability created through a one-shot investment. Capabilities that provide enduring sources of competitive advantage are usually built over time through a series of investments in facilities, human capital, and knowledge."* [180, p79]

Maritan & Lee [181] build on this perspective. Efficient product manufacture arising from investments in physical assets is only part of the value these investments bring. When combined with human resources and organisational processes that unlock its potential, the result is an increase in manufacturing flexibility and an ability to not only support current strategies but also a means of being agile enough to react in a timely manner to dynamic events. In financial terms the asset has an 'option value' that is rarely considered during the investment evaluation process.

The real return on investments like this therefore consists of two elements

*"... one component associated with the tradeable resources that are purchased and a second component associated with firm-specific, nontradeable resources, such as the knowledge, skills, and organisational processes with which the purchased resources are bundled. It is this latter component that potentially makes the same acquired asset more valuable to one firm than to its competitors."* [181, p2612]

Production investments need to satisfy the requirements of both new product developments and the development of the firm's competitive position in terms of its competitive capabilities [167, p71]. The nature and development of manufacturing's competitive capabilities are discussed in the next section.

### **2.3.7 Competitive Capabilities**

Peng et al [182] and Schroeder et al [183] provide thorough typologies of manufacturing competitive capabilities and similar terms used in the literature. For the purposes of this review the most common prime capabilities are considered – quality, dependability, speed (or flexibility) and cost.

Numerous authors argue that it is important to build manufacturing capabilities to create and maintain alignment with the business strategy and to create flexibility, for example Gupta & Lonial [171], Swink & Hegarty [184], and Brown & Blackmon [8] who make the distinction between the more traditional concept of strategic *fit* (alignment) and the extension to strategic *flexibility* which emphasises a more dynamic consideration.

*“Clearly what is needed is an approach to manufacturing strategy that simultaneously considers how both market requirements and manufacturing capabilities can be matched to competitive strategy in a dynamic and unpredictable competitive environment to sustain competitive performance.” [8, p798]*

There have been two major schools of thought as to how firms develop competitive capabilities. The first is underpinned by the principle of focusing on a single capability at the expense of others – capability trade-offs. This has been followed by the theory that capabilities can be built cumulatively over time. These two concepts are discussed next.

### 2.3.7.1 Capability Trade-Offs

Skinner [185] has been a leading proponent of the ‘focused factory’ where a manufacturing firms’ competitiveness is enhanced by focusing on (ideally) a single capability dimension – effectively ‘trading-off’ other dimensions in favour of the prime capability. Major characteristics of the focused factory include [185, pp115-6]:

1. *Process technologies – only one new and uncertain technology at a time.*
2. *Market demands (order winning criteria, e.g. quality, price, lead-time) – a superb job can only be achieved on one or two dimensions.*
3. *Product volumes – must be comparable across the product range*
4. *Quality levels – common attitude across the product range*
5. *Manufacturing tools (systems) – only one or two in use*

Skinner’s reason for this degree of focus is that the alternative introduces confusion and compromise ultimately leading to increased costs and inefficiency.

*“Too many companies attempt to do too many things with one plant and one organization. In the name of low investment in facilities and spreading their overheads, they add products, markets, technologies, processes, quality levels, and supporting services which conflict and compete with each other and compound expense ... The result is complexity, confusion, and worst of all a production organization which, because it is spun out in all directions by a kind of centrifugal force, lacks focus and a doable manufacturing task ... the result is a hodgepodge of compromises.” [185, p116]*

Hill [163] and Richardson et al [186] concur with Skinner’s call for focus – the inability for operations units to be ‘all-things-to-all-men’. Hill bemoans the tendency for a drift into unfocused territory as the production unit tries to satisfy too many product order-winning criteria at the same time.

*“Marketing-led strategies are usually based on the principle of growth through extending the product range. Invariably what happens is that new products (even those requiring new technologies) are manufactured, partly at least, on existing processes and almost always within the same infrastructure. The logic for this is based on the principle of the economies derived from using existing plant capacity where possible and being supported by the existing overhead structure. Over time, the incremental nature of these marketing changes will invariably alter the manufacturing task.” [163, p101]*

There are, however, disadvantages in creating a highly focused operations unit. Gerwin argues that it can lead to an inefficient use of resources and a lack of responsiveness when the competitive environment changes [187, p399]. This view is supported by Johansen & Riis who suggest that there is a danger of highly focused firms falling into a ‘competency trap’ [188, p208]. Such a trap may occur as a result of market or technological discontinuity. If the firm operates in a narrow field they may not pick up on the warning signs that change is imminent.

Skinner and colleagues (Brumme et al [189]) recently revisited the theory of the focused factory and continue to extol its virtue. They argue that while focus remains key, the direction of focus can shift over time to meet market demands – for example, from ‘innovation mastery’ to ‘operational excellence’ to ‘solutions delivery’. It is

recognised that resources and processes need to adapt to achieve this focus shift and that factory operations are:

*“... stubbornly resistant to change as processes, equipment, capacity capability, and infrastructures such as information systems, scheduling, worker skills and attitudes all tend to be resilient and complex to change.”*

[189, p1513]

In spite of the obvious parallels with path dependency, idiosyncratic resources and technological trajectories, somewhat surprisingly Brumme et al make no mention of the related literature of dynamic capabilities or resource orchestration.

The ability to be competitive across multiple capabilities is obviously desirable and has led to the proposition that organisations can, in fact, develop competitive positions across multiple capabilities and that the capabilities are built cumulatively.

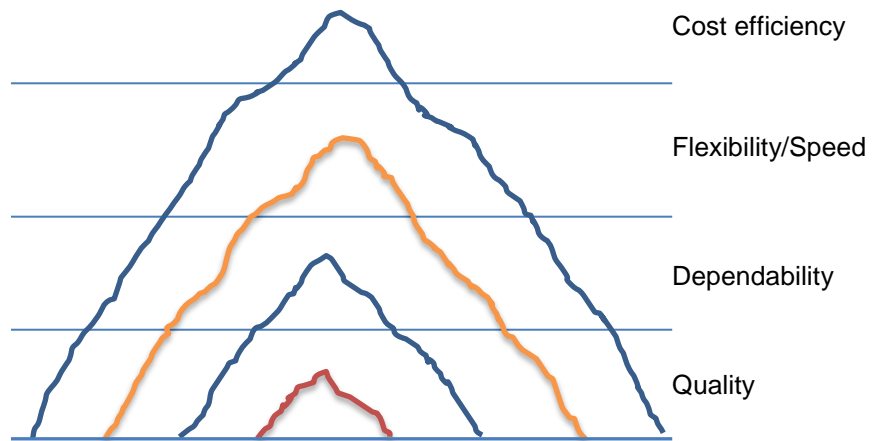
### 2.3.7.2 Cumulative Capabilities

Ferdows & De Meyer [190] challenged Skinner’s ‘trade-off’ or ‘focused’ approach in respect of manufacturing capabilities by saying that capabilities can be built cumulatively without an associated trade-off. Their contention is that the four prime manufacturing capabilities can be built cumulatively in a specific order: quality → dependability → reaction/flexibility speed → cost. Capability building from a foundation of quality through to the higher order capabilities of flexibility and cost implies a hierarchy that does not work in the reverse order [190, p179]. Improvement initiatives should follow the sequence suggested or initiatives will not have the desired effect.

Ferdows & De Meyer graphically represent this using their ‘Sand Cone’ model shown in figure 14. Note how ‘lower-order’ capabilities must be developed further (i.e. the base of the sand cone must be wider) in order to support the development of ‘higher-order’ capabilities.

*“Capabilities built in this way become formidable competitive weapons; they cannot be easily or quickly matched by competitors. Embarking on this course requires a commitment to expand the role of manufacturing in the competitive strategy of the company. Otherwise, the arguments for going directly after one capability at the expense of the others will prevail.”* [190, p181]

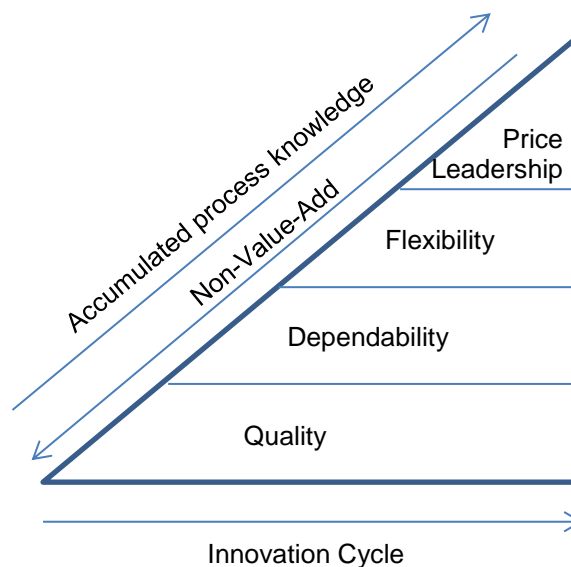




**Figure 14 – Manufacturing Capability Sand Cone Model**  
(Ferdows & De Meyer [190, p175])

Noble observes that ‘flexibility’ and ‘cost capabilities’ are reversed in the hierarchy in some studies, but that both always occupy a ‘higher-order’ capability position. She also argues that innovation – defined as rapid and frequent new product introduction – is a fifth competitive capability at the top of the sand cone [191, p696].

Roth [192] developed an alternative to the sand cone model – her ‘Competitive Progression Theory’. Roth’s progression of knowledge-based competences is shown in figure 15.



**Figure 15 – Progression of Knowledge-Based Competences**  
(Roth [192, p34])

The theory is very similar to the sand cone model, the subtle distinctions are that Roth argues it applies repeatedly across innovation cycles and that the ultimate outcome of simultaneous competitive capabilities is strategic agility.

*“Having higher levels of combinative generic capabilities is the essence of strategic agility, and the most cost-effective path of accumulating generic capabilities follows from competitive progression theory.” [192, p34]*

Liu et al [193] contrast the competitive capabilities ‘trade-off’ approach as suggested by Skinner and the cumulative capability building as proposed by Ferdows & De Meyer and Roth. Liu et al conclude that the cumulative model better reflects a balanced strategy and therefore leads to superior business performance, and that it is likely that this is due to the increased resources devoted by the business in order to develop the desired cumulative capabilities [193, p1277].

### 2.3.7.3 Creating a Balance of Capabilities

A construct borrowed from the strategic management literature has been applied by several authors in the context of achieving balance of manufacturing capabilities – ambidexterity, the effective deployment of both exploitative and explorative initiatives (discussed in section 2.2.4).

Kristal et al argue that ambidexterity in an organisation leads to *‘multiple and diverse competencies’* [194, p419] and Patel et al [195] find that operational ambidexterity is an enabler of generating firm performance from manufacturing flexibility:

*“... operational ambidexterity is central to increasing returns from manufacturing flexibility. Operational ambidexterity helps channel learning efforts to maintain continuity with prior routines while incorporating novel processes.” [195, p211]*

Interestingly, Tamayo-Torres et al in 2011 [196] initially find that manufacturing flexibility actually enhances exploration and exploitation, whereas Tamayo-Torres et al in 2017 conclude that ambidexterity *‘acts as an enabler across each of the stages of the sand cone (i.e. quality, speed, flexibility & cost) and hence drives manufacturing performance’* [197, p292]. So according to this research group operational ambidexterity and manufacturing flexibility are, in fact, mutually supportive.

Peng et al [182, 198] take the ambidexterity construct a stage further by drawing parallels between exploitation and ‘improvement capability’, and between exploration and ‘innovation capability’. Thus following the usual call for high levels of ambidexterity

organisations are encouraged to balance improvement and innovation capabilities at the operational level for maximum performance.

#### 2.3.7.4 Capability Trade-Off vs Cumulative Capability Perspectives

The discussion and difference of opinion continues to be expressed as to which of the capability development mechanisms occurs in practice. Some authors contend that the trade-off model is pre-eminent [189], while others argue that this has been superseded by the cumulative model [193]

Singh et al take a slightly different view in that rather than operating under a theoretical paradigm over which it has no influence, the firm itself consciously chooses which approach to take – either trading-off capabilities, building them cumulatively, or a hybrid approach between these extremes [199, p4014]. Their research concludes that in general the trade-off model is not chosen at all, while different versions of the cumulative capability model is used extensively.

Thürer et al argue that capability trade-offs relate to the competitive position of the firm whereas cumulative capabilities simply relate to performance improvements [200, p1165]. This insight is reflected and extended in the next section where the situations in which the trade-off model and the cumulative capability model can legitimately co-exist is reflected in the Theory of Performance Frontiers.

#### 2.3.8 The Theory of Performance Frontiers

Porter [201] examines the concept of a 'productivity frontier' which represents the best-in-class practices that can be achieved by an organisation. He argues that a firm moves closer to the frontier as it improves its operational effectiveness through investment in physical assets, human resources and systems. Industry competition will inevitably shift the productivity frontier out '*effectively raising the bar for everyone*' [201, p63].

Porter concludes that the need to trade-off competitive priorities and subsequent capabilities only becomes apparent as you operate close to the productivity frontier.

The Theory of Performance Frontiers as proposed by Schmenner & Swink [1] is subtly, but critically, different in that the frontiers in question relate to the best performance that can be achieved with an organisation's available structural and infrastructural resource and capabilities. So it is a measure of performance against an *internal* frontier – not an industry frontier as discussed by Porter.

Schmenner & Swink define a performance frontier as *'the maximum performance that can be achieved by a manufacturing unit given a set of operating choices'* [1, p108]. The frontier is created as the cost to incrementally improve performance becomes disproportionately expensive. They suggest that, in fact, there are two frontiers – an *asset* frontier which is created by equipment investment and plant design, and an *operating* frontier which is formed by the choices made in how those assets are put to use.

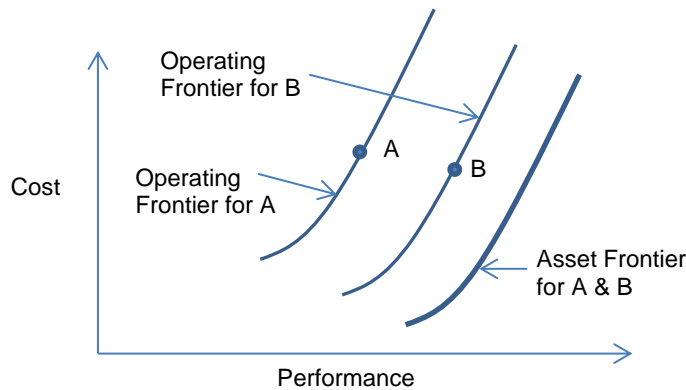
*"The asset frontier is altered by the kinds of investments that would typically show up on the fixed asset portion of the balance sheet, whereas the operating frontier is altered by changes in the choices that can be made, given the set of assets that the plant management is 'dealt'."* [1, p108]

Schmenner & Swink contend that if a firm is far from its asset frontier, then capabilities can be built cumulatively, but as soon as the asset frontier is approached then trade-offs come into play. Changes to the asset frontier require significant investments.

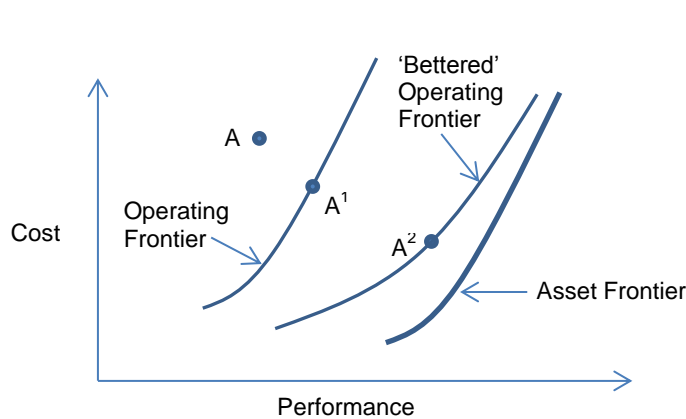
*"Plants that are not near their [asset] frontiers are not likely to enjoy as high returns on these investments because the frontier is largely irrelevant to them. Instead, a plant in this condition would benefit more from a cumulative improvement approach aimed at improving infrastructure and operating efficiencies such as quality-related improvements."* [1, p111]

This theory therefore explains how and when both the capability trade-off model and the cumulative capability model come into play in the same organisation. Firms can improve performance by driving out inefficiencies in order to approach its operating frontier. In this area capabilities can be built cumulatively. Further improvements in performance can be made by changing operating systems and policies to achieve 'betterment' of the operating frontier, moving it closer to the asset frontier (Boer et al [202, p1235]). It is at this point that capability trade-offs are most likely to be experienced.

This is graphically represented in figure 16.



Firm A is likely to be able to build capabilities cumulatively while firm B, due to diminishing returns on improvement, is more likely to be subject to capability trade-offs.



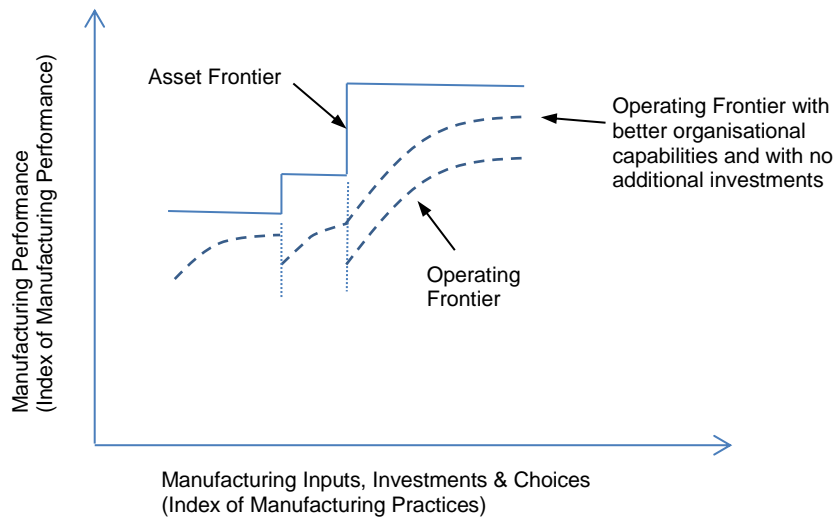
Plant A is underutilized and inefficient. Rationalizing resources and resolving inefficiencies leads to position A<sup>1</sup> at which the plant encounters its operating performance frontier. Operating policy changes improve the frontier and move the plant to position A<sup>2</sup>, where technological and asset constraints begin to significantly affect performance.

**Figure 16 – The Theory of Performance Frontiers**  
(Schmenner & Swink [1, pp108-9])

Vastag [7] refines and extends Schmenner & Swink's theory to apply to a broader range of operations management issues. Vastag also substitutes Schmenner & Swink's diagrammatical axes from 'performance' and 'cost' to a manufacturing performance index and a manufacturing practices index respectively. These indices are defined as [7, p355]:

- Practices Index – manufacturing inputs, investments & choices
- Performance Index – aggregation of capacity, cost, quality, product range

Vastag's reconfigured graphical version of the theory is shown in figure 17.



**Figure 17 – The Theory of Performance Frontiers**  
(Vastag [7, p355])

Asset investments cause step changes in the asset frontier. The operating frontier is concave due to the law of diminishing returns in improvement initiatives. Vastag suggests that there is an optimum gap between the two frontiers – an “asset utilisation” measure. Too close to the asset frontier restricts flexibility and introduces trade-offs, but too far away will not exploit the assets invested in.

Rosenzweig & Roth [203] and Chung & Swink [204] support Schmenner & Swink’s proposition that the firm’s position relative to its performance frontier will influence whether capabilities can be built cumulatively or whether trade-offs are inevitable. Thüerer et al [200] suggest that trade-offs only need to be made in high-performing businesses where external competition drives firms to make choices as to which capabilities should be prioritised – the firm is close to its asset frontier.

Research in the airline industry by Lapre & Scudder [205] and Ramdas & Williams [206] demonstrate empirical validation of the theory, although their use of best-in-industry measures of performance frontiers as opposed to internal metrics is contrary to the Schmenner & Swink approach. This is pointed out by Nand et al [207] in their subsequent work in the airline industry.

Nand et al’s [207] more recent analysis of Schmenner & Swink’s work provides yet more clarity of reasoning for the frontier positioning (and the consequences of that positioning):

*“The practical implication of this insight is that firms that are on the leading edge (i.e. operating close to the asset frontier) will have to make trade-offs in order to change their competitive position unless they are able to create some sort of innovation that moves the asset frontier itself. The rationale for this is that if a firm’s effective capacity and theoretical capacity converge, choices for combination and re-arrangement of methods and systems to build further capabilities are limited.” [207, p892]*

The size and diversity of a business’s product portfolio – its product portfolio architectural complexity – will affect the position of the operating frontier relative to the asset frontier according to Jacobs & Swink [208, p687]. Vastag also makes this point and suggest that the operating frontier changes (instantly) as different product mixes are applied to a set of manufacturing assets [7, p356].

Cai & Yang [209] contend that the dimensions of operating and asset frontiers are different and that it is the operating frontier that offers the most potential for sustained competitive advantage.

*“In this sense, the concept of an asset frontier is similar to design capability (maximum output that can be obtained); whereas, the operating frontier is similar to effective capability (the maximum output, given operating hours, product mix, scheduling effectiveness, delays, and machine maintenance).” [209, p132]*

*“The asset frontier is based on tangible resources; whereas, the operating frontier is related to intangible resources. The latter thus represents unique resources, which are valuable, rare, and specific to a given firm. Such resources are more important for offering a sustained competitive advantage than the asset frontier.” [209, p132]*

Research by Liu et al [193] and Power [210] demonstrate that operating and asset frontiers tend to converge over time as organisations incrementally exploit the capabilities of their suite of assets. This ultimately leads to diminishing returns on investment in continuous improvement activities [210, p1185].

Power argues that as the operating frontier and asset frontier converge over time this limits the ability to develop competence. He creates a sense that as investment in the

asset frontier is made it creates room to develop the operating frontier as experience in using the new capital equipment grows.

*“... while the performance frontier (and therefore competence) extends due to further asset investment over time, the physical limits of technology also come into play. When technologies (methods, systems, physical assets, etc.) mature, operations and asset frontiers will tend to converge reducing the opportunities for creating improvement over time (capability) in performance. Innovation then becomes the primary potential source of differentiation between plants in industrialised economies.” [210, p1190]*

The Theory of Performance Frontiers has demonstrated how the concepts of capability trade-offs [185] and cumulative capability building [190] can be reconciled in a single organisation. The ‘distance’ between the operating and asset frontiers will either provide ‘room’ for capabilities to be developed cumulatively (if the distance is larger), or it will potentially constrain capability development and introduce trade-offs (if the distance is smaller).

The ability to develop higher order capabilities such as flexibility and agility (and innovation, according to Noble [191]) relies on maintaining ‘sufficient’ distance between the two performance frontiers.



### 2.3.9 Resource & Manufacturing Strategy Literature Summary

Key themes from the Resource Based View of the firm and the manufacturing strategy body of literature are presented below with selected references cited.

- The resource-based view of the firm provides an alternative view of competitive strategy that recognises that the idiosyncratic nature of assets, resources and competences can form the basis of competitive advantage for organisations [104].
- A firm's competences are hard-won assets that are built over time and not bought [104]. They have followed a 'technological trajectory' that at a point in time leave individual firms with a constrained and somewhat unique set of paths open to it from which to choose its future competitive strategy [91].
- 'Dynamic capabilities' – as distinct from *operational* competences – enable businesses to *sense* and *seize* strategic opportunities by *reconfiguring* existing competences and developing new ones [119]. Managers achieve this reconfiguration by asset and resource *orchestration* [139].
- A firm's ability to identify, assimilate and exploit new knowledge is its 'absorptive capacity' and this is an essential organisational quality to allow the effective development of new operational capabilities [146-148]. It is critical in enabling the firm to understand its own technological trajectory and the opportunities and limitations that that trajectory presents [151].
- Manufacturing (or operations) strategy has been subservient to business strategy for some time [162]. The body of strategic management literature is considered to have developed separately from the manufacturing strategy literature. This is reflected in the reactive way manufacturing strategy is developed by managers who are seeking primarily to achieve simple alignment with their overarching business strategy. The opportunity for manufacturing to take a more pro-active role in strategy formulation is often overlooked [8, 9, 173].
- The traditional call for factories to be focused on a key competitive dimension (or manufacturing task) has largely matured to reflect the view that operations units can be competitive across multiple dimensions. This is described in the 'cumulative capability model' and 'competitive progression theory' [190, 192].
- The Theory of Performance Frontiers demonstrates how a firm can unlock the potential for high performance on higher-order competitive dimensions (e.g. flexibility and agility) by effective management of its asset and operating frontiers [1, 7, 209].

## 2.4 Research Focus

It is clear that in manufacturing organisations that wish to be innovative in order to grow and to ensure long term competitiveness, the areas of literature relating to strategic management, innovation management, the resource based view of the firm and manufacturing strategy are very relevant.

The literature review presented in this chapter has revealed that these areas of literature have been developed largely independently with some cross-references but with little overlap. The role that a firm's idiosyncratic resources – both as a constraint and as an enabler – could and should play in competitive strategy development is not given sufficient weight in strategic management or innovation management literature.

*“With the rising popularity of core competencies and their related concepts of key and distinctive capabilities, there is an emerging picture that a potentially very large percentage of manufacturing industry has only a loose understanding and appreciation of this relatively new approach of thinking about competitive strategy.”* (Bhamra et al [102, p2730])

It has been the experience of this author that strategy formulation in the manufacturing businesses he has been employed in have indeed reflected Bhamra's contention. Manufacturing strategy is often exclusively reactive to the requirements of business strategy, rarely initiating strategic contributions that positively shape strategic direction at the business level. This author has illustrated this unbalanced approach to strategy formulation in senior management discussions using the simple diagram in figure 18.

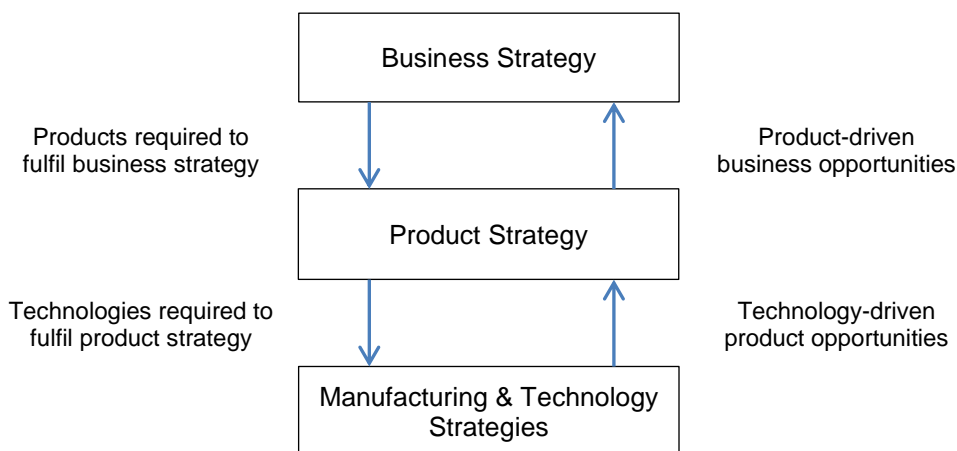


Figure 18 – Strategy Formulation

Typically strategy formulation flows down the left side of figure 18. Manufacturing strategy is derived from assessing which technologies are required to deliver the products identified by the business strategy. What is often missing is for production units to pro-actively influence business strategy through the strategy-building arrows on the right side of figure 18. Opportunities arising from technological competences of the operations unit that may influence product strategy and thence business strategy can be overlooked. Firms should aim to develop strategy exploiting both strategy-building paths. It is likely a strategy development cycle will *start* with business strategy, but thereafter should ideally be iterative in nature.

The corporate strategy arising from this process (whether derived from a predominantly outward-looking competitive strategy approach or more ideally via a balanced, iterative approach incorporating resource-based perspectives) must be deployed in the organisation. The process of strategy deployment through stages of innovation management, product portfolio planning and resource orchestration should result in operations units being aligned with business and innovation strategic intents, while being sufficiently agile to respond to a dynamic environment.

Extracting the most relevant elements of the literature map of figure 1 and presenting them as a simplified linear process in figure 19 below shows how key strategic activities translate corporate strategy into an agile and effective operations unit.

As has been seen in the literature review, innovation strategy comprises both deliberate and reactive (emergent) elements which are designed to serve the overarching corporate strategy but are significantly influenced by the organisational context. The context comprises external factors such as market and technological turbulence as well as internal factors predominantly residing in the attitudinal position of the senior management team. This 'posture' of the firm's decision-makers is framed by the dominant logic of the business built up through past successes and failures as well as the group's innovation 'orientation' and its propensity to innovate.

The output of the innovation strategy drives product portfolio planning by appropriately allocating resources to both exploitative and explorative projects. In the operations arena, due to the time for new resource configurations to become effective, it is ideal if resources are appropriately 'orchestrated' to *anticipate* product development projects.

New configurations of existing assets and resources, combined with any technology acquisitions, serve to modify the profile of a firm's operating and asset frontiers. The relative position of these frontiers will affect the ability of the manufacturing unit to

develop or extend the higher-order competitive capabilities – flexibility and agility – that provide the business with strategic contingency to deal with a dynamic environment.

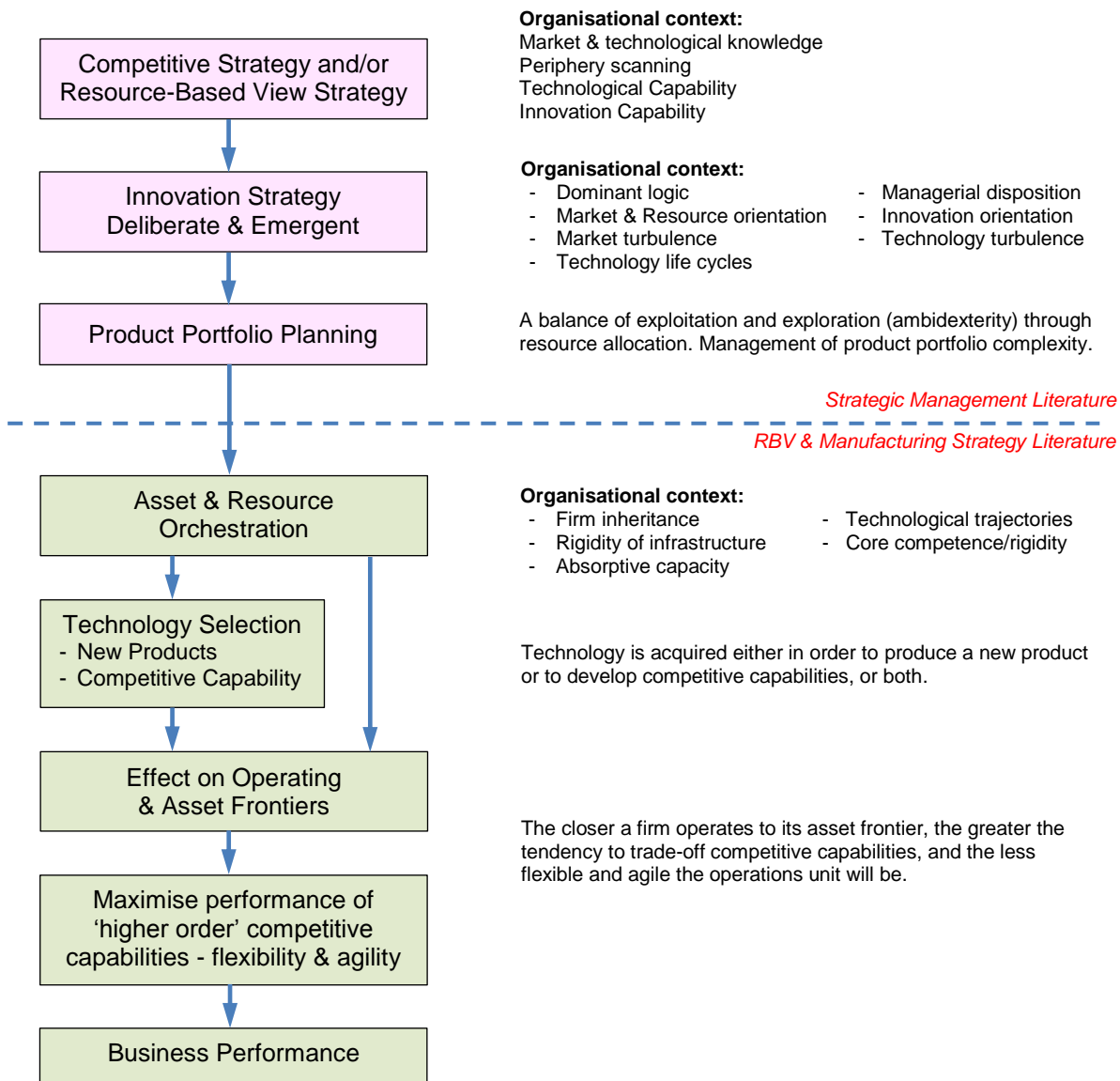


Figure 19 – Research Focus

In reviewing the literature there appears to be a boundary (shown as a dotted line in figure 19) between the strategic management literature (elements above the line) and the RBV and manufacturing strategy literature (elements below the line).

In seeking to address the research objective to understand how heavily-invested manufacturing firms can be innovative – which necessarily requires a level of agility – the hypothesis development chapter that follows will propose that there is a relationship between innovation strategy development (strategic management literature) and manufacturing performance frontiers (operations management literature) – a relationship that has not been explored in the literature to date.

## Chapter 3: Hypothesis Development

### 3.1 Theoretical Arguments

The tendency for strategic management literature to dominate innovation management thinking, and the focus of operations management research on a reactive and subservient alignment with business strategy, has led to the position where the relationship between a firm's approach to innovation management and the development of its manufacturing capabilities is inadequately understood and detrimentally exposed in dynamic environments [8]. The purpose of this research and the hypotheses that follow is to explore and characterise this relationship.

Strategy development becomes less 'deliberate' and more 'emergent' in nature in turbulent environments – where this turbulence can be due to economic, competitive or technological factors [13, 96]. In this situation organisational context becomes very important, as it constrains the range of responses open to an organisation in its attempt to maintain its sustainable competitive advantage through innovation [119, 125, 151]. Firms that have developed effective long-range knowledge and absorptive capacity are likely to be in a position to be more deliberate in their planning and limit the emergent nature of their strategy development.

In addition to innovation, another component of sustainable competitive advantage is the alignment between business and manufacturing strategy [9]. Achieving and maintaining alignment between business and operations in dynamic environments requires a degree of flexibility and agility. Eshima & Anderson observe that a firm's 'adaptive capability', i.e. its agility, is related to its ability to make new resource combinations [101, p770]. This view is also reflected by Nason & Wiklund who contend that resource versatility leads to firm growth in uncertain environments [211, p52].

Teece et al [212] underline the importance of agility when operating in today's innovation economy but warn against simply maintaining excess resources and capacity to create organisational 'slack' – this is a much too simplistic and inefficient tool to create agility. They recommend the deployment of dynamic capabilities to more deliberately orchestrate resources to manage the trade-off between agility and efficiency [212, p24].

Deliberately positioning operating and asset frontiers sufficiently far apart so that the development of 'higher-order' competitive capabilities – flexibility and agility – is not

constrained [209, 210], responds to Teece's recommendation to balance agility and efficiency.

Given the temporal differences between strategic decisions responding to a dynamic environment and the ability to overcome the inherent inertia of moving operating and asset frontiers, it is important to create room between the frontiers to facilitate the intended strategy and ensure innovation can be realised in a timely manner. Vastag comments on this gap between the operating frontier and asset frontier:

*“Generally, there is a pressure to minimize this distance and keep the operating frontier as ‘close’ to the asset frontier as possible through ‘utilizing’ (using this term in the traditional capacity utilization sense) the production potential of the assets. The primary advantage of doing so is the potential to reduce unit cost. However, Schmenner & Swink [1] argue very persuasively that the law of diminishing returns and diminishing synergy may make it undesirable after a certain point to move the operating frontier closer to the asset frontier. Moreover, high capacity utilization tends to reduce flexibility and as a result in each firm, industry, and country there is an asset utilization level that is considered normal and acceptable.” [7, p357]*

Therefore it is proposed that it is desirable to have an optimised distance between the operating frontier and asset frontier to minimise competitive trade-offs on the one hand and at the same time be efficient and ‘sweat the assets’ on the other. The distance between the two frontiers can be created by a managed process of development of assets, ahead of specific product-driven requirements.

The complexity of the product portfolio also plays a key role [208]. With higher portfolio complexity the product mix is more likely to change suddenly which instantly affects the distance between the operating frontier and the asset frontier. Portfolio mixes with a higher degree of exploration (when compared to exploitation) will tend to put demands on the operating frontier, closing the gap to the asset frontier.

This research proposes that successful firms with an aggressive innovation posture and a propensity to innovate should maintain a larger gap between the operating frontier and asset frontier in order to cater for their innovation efforts – particularly in an environment of market and technological turbulence.

Put another way, a firm that has a higher propensity for innovation should extend the asset frontier out in front of the operating frontier by a greater degree than may be explicitly required by its product development strategy. This would in effect be trying to anticipate medium term needs that are perhaps not yet fully formed in management's thinking. This approach is in line with the most advanced stage – stage 4 – of Hayes & Wheelwright's model of manufacturing's competitive potential [162, p396] (see table 5 in section 2.3.5.1) which is characterised by:

- *Efforts made to anticipate the potential of new manufacturing practices and technologies.*
- *Long range programmes pursued in order to acquire capabilities in advance of needs.*

This approach would negatively affect traditional return on investment metrics because assets would either appear to be over-specified or acquired before they are strictly needed. Traditional investment decision-making processes do not account for this capability-building 'option value' of the asset [181]. However this approach should bring longer term security, by always ensuring the optimum operating frontier position can be achieved under a variety of future scenarios.

The corollary of this proposition is that 'unmanaged' operating and asset frontiers are allowed to develop reactively, often incurring trade-offs and un-competitiveness while frontiers are moved only in response to short-term needs.

It is the proposition of this research that for the optimum firm performance the gap between the operating and asset frontiers must be sufficient to cater for the degree of emergent (as opposed to deliberate) strategy development and the innovative propensity of the firm. This has direct implications for asset investment strategy and should lead to an objective framework to justify investment in assets and infrastructure beyond that that can be justified by traditional asset investment evaluation methods.

## 3.2 Research Objectives

There are two distinct elements to the research objectives.

Firstly, can the distance between a firm's operating and asset frontiers (**hereafter OF and AF**) be reliably measured. Secondly, if the gap can be measured how does it relate to the firm's innovation propensity, its relative bias towards emergent strategy development (as opposed to deliberate strategy development) and the market and technological environment it operates in.

### 3.2.1 Performance Frontier Gap Measurement

Although measurements of OF and AF have been used comparatively on an industry-wide basis (e.g. Lapre & Scudder [205], Ramdas & Williams [206]), this is not the approach that will be taken in this research. Wernerfelt contends that a firm's asset stock coupled with non-linear managerial behaviour leads quickly to idiosyncratic asset positions [112, p1369]. This results in correspondingly unique OF and AF profiles – making inter-firm comparisons of individual OF and AF profiles unreliable. Therefore for the purposes of this research the approach of using within-firm comparisons will be used, as suggested in the originating Schmenner & Swink [1] theory and subsequently recommended by Nand et al [207].

There is limited precedent for separate, absolute measures of a firm's OF and AF; one example is in the airline industry [205, 206]. These measures were specific to that industry and not generally applicable to a broad range of manufacturing industry. Also separate measures of a firm's OF and AF can only be converted to a measure of the gap between them if they are on comparable scales. Given the very different dimensions of the asset frontier and the operating frontier [209] it is not reasonable to pursue this approach.

The alternative is to directly measure the OF-AF gap. There appears to be no precedent in the literature for direct measurement of the OF-AF gap so the first objective of this research is to develop and validate a new measure of this important characteristic of a manufacturing organisation. Ideally this measure should be realised as a numeric scale to facilitate comparisons and analysis between firms.



## 3.2.2 Research Hypotheses

If the OF-AF gap measure can be successfully established a series of hypotheses will be analysed. The hypotheses are divided into two groups – those considering *correlations* and those considering *causality* between variables.

### 3.2.2.1 Correlation Hypotheses

With the exception of when major technological or market discontinuities occur and organisations become paralysed into inaction [13], environmental turbulence triggers organisations to respond innovatively [23]. Therefore in industries experiencing greater environmental turbulence firms are likely to have a greater propensity to innovate.

*Hypothesis 1 – Firms in turbulent environments have higher levels of innovation propensity*

Firms that have a propensity to innovate, particularly in turbulent environments, need to have agile decision-making processes and there can be temptation to react instinctively to new information as it emerges. However, for those companies who take a longer term perspective and are better prepared [18], innovation propensity results in more responsive, deliberate and focused strategy development [101].

*Hypothesis 2 – Firms with higher levels of innovation propensity develop strategy with lower levels of emergent strategy bias.*

Strategy development becomes less ‘deliberate’ and more ‘emergent’ in nature in turbulent environments [13, 96] although the outcome of this emergent strategy development can often be for the firm to ‘withdraw into its shell’ and actually become more inert in order to weather the storm (Stieglitz et al [213, p1854]).

*Hypothesis 3 – Firms in turbulent environments have higher levels of emergent strategy bias.*

Organisations with a propensity for innovation will extend the asset frontier out in front of the operating frontier in order to create the space to realise their innovative efforts.

*Hypothesis 4 – Firms with a greater innovative propensity have a larger OF-AF gap.*

Reconfiguring resources to effect changes in the positions of operational or asset frontiers requires deliberate strategic actions. It is likely that businesses operating in a predominantly emergent strategy development mode will not have a significant distance between their operating and asset frontiers.

*Hypothesis 5 – Firms with high levels of emergent strategy bias have smaller OF-AF gaps.*

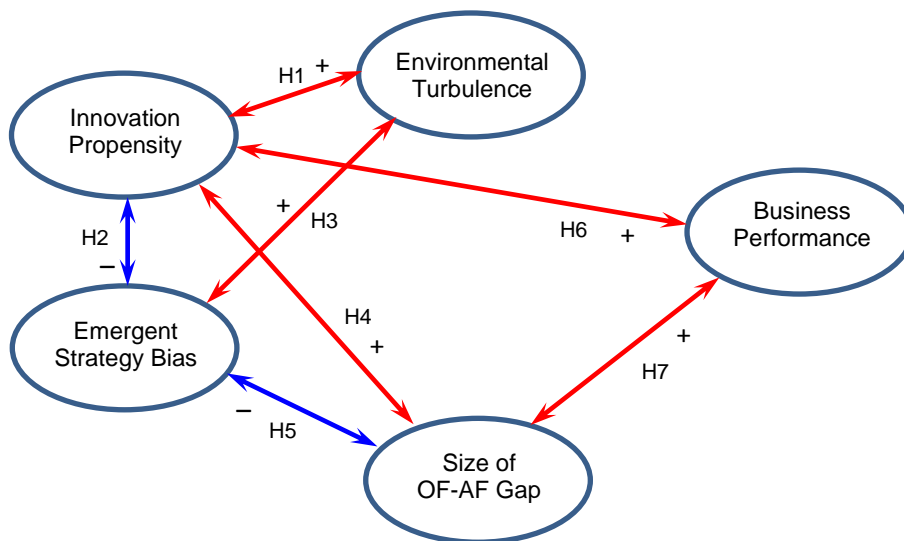
Organisations are encouraged to be innovative in order to achieve long term success [3]. Firms that are innovative tend to grow more quickly in terms of employment and sales [4]. It is therefore reasonable to hypothesise that a firm’s innovation propensity is positively linked to its overall performance.

*Hypothesis 6 – Greater innovative propensity positively correlates with firm performance.*

Businesses that manage the size of OF-AF gap to avoid capability trade-offs and to enhance agility are likely to outperform those that focus solely on exploiting existing asset portfolios.

*Hypothesis 7 – A larger OF-AF gap positively correlates with firm performance.*

The seven hypotheses above are shown in the correlation hypothesis model in figure 20.



**Figure 20 – Correlation Hypothesis Model**

### 3.2.2.2 Causality Hypotheses

Building on the correlation hypotheses above, this research proposes that for four of the correlations there is a degree of causality.

*Hypothesis 8 – Turbulent environments **cause** firms to have higher levels of innovation propensity*

*Hypothesis 9 – A firm’s innovation propensity **causes** them to have a larger OF-AF gap.*

*Hypothesis 10 – A firm’s innovation propensity **causes** better firm performance.*

*Hypothesis 11 – A larger OF-AF gap **causes** better firm performance.*

The four hypotheses above are shown in the causality hypothesis model in figure 21.

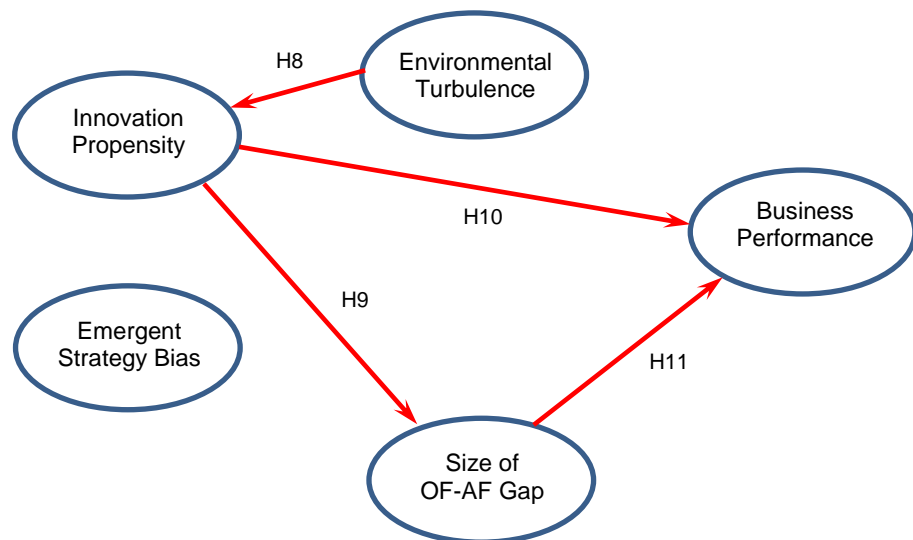


Figure 21 – Causality Hypothesis Model

The relative strength of correlation and degree of causality between the variables will reveal the role the size of the OF-AF gap plays in linking innovation propensity and emergent strategy bias to business performance.

## Chapter 4: Research Methodology

This chapter presents the research methods to be employed in order to deliver the research objectives described in chapter 3. In doing so the underpinning theoretical assumptions that have led to the choice of those methods will be discussed. The chapter starts with a review of research philosophies and approaches, and then describes three similar models of the hierarchy of decisions that must be made in order to move from the philosophical perspective through to a detailed research design in a justifiable and logically consistent manner. One of these three models is then used as the framework within which the particular methods for this research are selected. In the last section of this chapter the research methods to be used are discussed before the actual research design is developed in detail in chapter 5.

### 4.1 Research Philosophy

#### 4.1.1 Introduction

Fundamentally, research concerns the creation of knowledge. It is therefore important to understand not only how knowledge is created but also what kind of knowledge is expected from the research and what philosophical assumptions are implicit in the methods chosen to create that knowledge (Crotty [214, p2]). The philosophical context of the research will determine *'what kinds of knowledge are possible and how we can ensure that they are both adequate and legitimate'* [214, p8]. So it is important to explain and justify the philosophical position that has been adopted that then underpins the research methods employed.

The philosophical stance that a researcher takes is sometimes influenced by practical considerations, however the main component is the researcher's *'particular view of what is acceptable knowledge and the process by which this is developed'* (Saunders et al [215, p128]). Research philosophy has been described as being comprised of three dimensions [215, p129]:

The nature of <b>reality</b>	<i>Ontology</i>
The nature of <b>acceptable knowledge</b>	<i>Epistemology</i>
The role of <b>values</b>	<i>Axiology</i>

These three dimensions are discussed in the next section.

## 4.1.2 Research Philosophy Dimensions

The three philosophy dimensions discussed below are often viewed as each having binary positions on opposing sides of an argument [215, p129], however more recent authors view each as a continuum along which positions can be taken at any point (e.g. Niglas [216]), the combination of which create many unique philosophical positions.

### 4.1.2.1 Ontology

Ontology considers the *nature of reality*. That is, how the world operates and whether its social entities are constructed and defined by external factors – **objectivism**, or whether those entities are as a result of the perceptions and actions of the individuals within them – **subjectivism** [215, p131]. This is the first potentially binary scale, and there are schools of management thought that are firmly in one camp or the other.

An organisation's management function itself can be seen as an example of *objectivism* insofar as roles, responsibilities, procedures and structure are laid down for those operating within the organisation. Management organisation and best practice is largely similar across different businesses and therefore independent of the individuals working within them [215, p131].

Taking a more *subjectivist* view would downplay the structural, objective aspects of management and be more concerned with how individuals interpret their roles and responsibilities and how they believe their jobs should be done [215, p132]. Taking this view requires considering the social interactions between people and the motives behind those interactions.

Saunders et al exemplify the contrast between objectivism and subjectivism by considering the different ways organisational culture develops in businesses. Objectivists '*would tend to view the culture of an organisation as something that the organisation 'has': something that can be changed and manipulated*', whereas the '*subjectivist's view would be that culture is something that the organisation 'is' as a result of the process of continuing social enactment*' and therefore much more difficult to directly influence [215, p132].

The ontology dimension of research philosophy appears not to be considered in isolation in many researchers' deliberations and is often conflated (and confused) with the epistemological dimension – a situation Crotty laments [214, pp10-11].

### 4.1.2.2 Epistemology

Epistemology is concerned with the nature of *acceptable knowledge*. There are three main outlooks defined along this continuum – **positivism**, **interpretivism** and **realism**.

*Positivism* adopts the approach of the natural scientist [215, p134] where data is only collected from an observable reality, and correlations and causal relationships lead to '*law-like generalisations*'. Typically, existing literature is analysed to generate theoretical positions and hypotheses that are then tested using the collected data. Research undertaken in this way should be 'value-neutral' to ensure that outcomes are objective and impartial [215, p135]. Blumberg et al contend that this approach relies on the assumptions that the social world is observed by collecting facts and that it can be reduced to simple concepts to facilitate examination [217, p20].

*Interpretivism* argues that the social nature of business is too complex to be subject to simple, overarching 'laws' and that it is necessary to understand and account for individuals' attitudes, perceptions and unique actions [215, p137]. Researchers interpret collected data against their own set of meanings, therefore it is important to adopt an empathetic stance during the research – '*the researcher is part of what is observed*' [217, p21]. This approach relies on '*seeing what meanings people give to [the social world] and interpreting these meanings from their viewpoint*' [217, p21]. Interpretivism does not therefore attempt to generalise findings across businesses.

*Realism* sits between the extremes of positivism and interpretivism on the epistemological continuum and combines principles of both [217, p22]. Realism, like positivism, accepts the natural scientific approach and that reality exists outside the individual. However it also incorporates the interpretivist view that '*understanding people and their behaviour requires acknowledgment of the subjectivity inherent to humans*' [217, p22]. This approach recognises forces working simultaneously at two levels. Firstly at the macro level, where social processes cannot be affected by the individual and therefore generalisations of correlations and causalities can be hypothesised, and secondly at the micro-level where individuals' idiosyncrasy creates unique local scenarios.

### 4.1.2.3 Axiology

Axiology considers the role the researcher's values play in the research. At one extreme the researcher is completely 'value-neutral' and at the other the researcher is

'value-bound'. To a large extent there is a link between the epistemological approach and the role of values [215, p140]. When taking a positivist approach the researcher is value-neutral by being independent of the data and maintaining an objective standpoint. Conversely, when the approach is interpretivist in nature the researcher and their values are effectively part of what is being studied [215, p140].

The three dimensions of research philosophy – ontology, epistemology and axiology – have been described above. As positions are adopted along each of these three continua a unique philosophical context for the research in question is created. However, there is a school of thought that this is somewhat unrealistic in practice [215, p130]. This outlook is defined as *pragmatism*.

### 4.1.3 Pragmatism

Pragmatists argue that the most important driver of the philosophical position on each of the three dimensions is not an abstract, theoretical ideal that is personal to each researcher, but rather the research question itself [215, p130]. Different philosophies *'are suited to achieving different things'* [215, p129].

Pragmatists believe that the practical outcomes of the research are more important than the concepts and ideas themselves and that there are often many ways to undertake research to develop understanding of the world. With this outlook, different philosophical positions can be taken for different elements of the research to potentially build a richer picture of reality [215, p130].

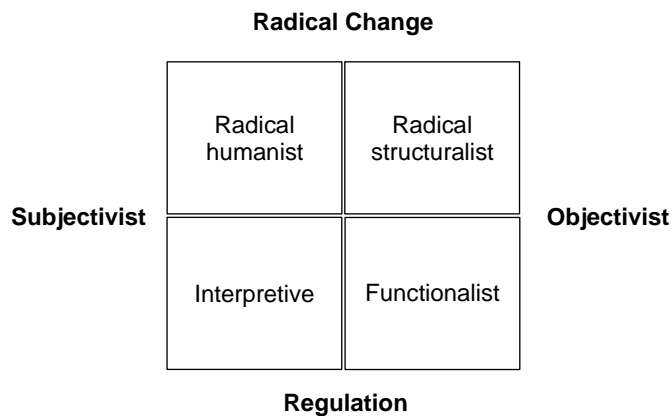
The multi-dimensional nature of research philosophy described in this section could result in potentially unlimited unique combinations. Several authors have categorised common combinations into a series of 'standard' approaches that researchers may choose to adopt. These have been variously termed philosophical 'paradigms' and philosophical 'worldviews', and are discussed in the next section.

### 4.1.4 Research Philosophy Paradigms & Worldviews

Particular combinations of the ontology, epistemology and axiology dimensions of research philosophy have been categorised to create short-hand labels for the most

common philosophical approaches. The simplified categorisation of approaches have been referred to as *'broadly conceived research methodologies'* (Neuman [218]), *'paradigms'* (Burrell & Morgan [219]) and *'worldviews'* (Cresswell [220]). These categorisations bring together the researcher's general orientation about the world as well as the specific nature of the research in question [220, p6].

Burrell & Morgan's fourfold categorisation of social science paradigms is shown in figure 22 [215, p141]. It combines the epistemological and ontological aspects of philosophy discussed above and presents them against two conceptual dimensions: subjectivist to objectivist, and regulation to radical change.



**Figure 22 – Four Paradigms for the Analysis of Social Theory**  
Developed from Burrell & Morgan (in Saunders [215, p141])

The first dimension in this typology – subjectivist/objectivist – is familiar from the discussion in previous sections, while the second dimension – regulation/radical change – is introduced specifically by Burrell & Morgan to describe two differing ways change is effected in an organisation. A regulated approach seeks to effect change within the framework of the way things are done at present, whereas a radical change emphasis *'approaches organisational problems from the viewpoint of overturning the existing state of affairs'* [215, p141].

The resulting four paradigms from these two dimensions are briefly summarised below:

**Functionalist Paradigm** – this is the paradigm within which most management research operates [215, p142]. The assumption is that businesses are rational, and that solutions to organisational issues can be found within the boundaries of the current management systems and structure.



**Interpretive Paradigm** – rationality is replaced by the importance of understanding the human interactions that combine to affect the way the business operates. It is more about explanation, rather than offering solutions.

**Radical Humanist Paradigm** – this paradigm emphasises the consequences of individuals’ actions and how they can manifest themselves in political terms to change the status quo.

**Radical Structuralist Paradigm** – here it is important to understand the structural nature of organisations such as hierarchies and reporting relationships that can lead to conflict and poor performance. Ultimately fundamental changes to the business may be necessary.

The purposes of this categorisation, according to Burrell & Morgan, are to help researchers clarify their own view of the world, to provide a simplified way to understand how other researchers work and to *‘help researchers plot their own route through their research’* [215, p141].

More recent work by Creswell resulted in a series of *worldviews* created for similar reasons to those of Burrell & Morgan’s *paradigms*. Creswell developed four worldviews: postpositivism, constructivism, advocacy/participatory and pragmatism. The main elements of these worldviews are shown in table 6.

<b>Postpositivism</b>	<b>Constructivism</b>
Determination Reductionism Empirical observation & measurement Theory verification	Understanding Multiple participant meanings Social and historical construction Theory generation
<b>Advocacy/Participatory</b>	<b>Pragmatism</b>
Political Empowerment issue-oriented Collaborative Change-oriented	Consequences of actions Problem-centred Pluralistic Real-world practice oriented

**Table 6 – Philosophy Worldviews**  
Creswell [220, p6]

Creswell’s four worldviews are briefly summarised below:

**Postpositivist Worldview** – this outlook is based in positivism (see section 4.1.2.2) but is more nuanced in that it allows that human behaviour introduces some uncertainty to a strictly objective position [220, p7]. Postpositivists create knowledge through making observations and measurements of the real world that are then used to support or refute a theory. Objectivity remains important through the application of validity and reliability tests of the data collected.

**Social Constructivist Worldview** – this worldview is borne out of a subjective ontology (see section 4.1.2.1) and interpretive epistemology (see section 4.1.2.2) where research is typically qualitative, with researchers attempting to understand the experiences and motivations of individuals. The researcher's objective is to *'make sense of the meanings others have about the world'* [220, p8]. This approach is designed to formulate theory from the research rather than to test theory.

**Advocacy & Participatory Worldview** – this position is specifically adopted to address the concerns of marginalised or disenfranchised groups in society. The outcome of the research is directly linked to a political agenda and a programme for change [220, p9]. Research is typically qualitative and critically it involves members of the social group in question.

**Pragmatic Worldview** – to some extent this worldview ignores the traditional philosophical dimensions described above and instead focuses clearly on the problem to be investigated (see also section 4.1.3). All available research methods should be considered for use to investigate the issue at hand [220, p10]. This therefore often leads to a mix of qualitative and quantitative methods being employed.

Paradigms and worldviews aim to help the researcher to frame the philosophical context for their work. This context is in part formed from the researcher's belief system, in part due to the nature of the issue to be researched and in part reflects the desired use to which the outcome of the research is to be put.

Once the research philosophy has been established the researcher must then make choices about the specific research methods to be used, methods that are both consistent with the research philosophy and that will deliver the desired research outcome. There are several research methodology models that link philosophy to research design and three of these are discussed in the next section.

## 4.2 Research Methodology Models

The research philosophy that is considered and adopted by the researcher is the starting point for subsequent decisions that need to be made regarding research methodologies and the detailed research methods themselves. Three models that conceptually represent this process and aid the researcher's understanding are presented below.

### 4.2.1 Crotty's Conceptual Model

Crotty's conceptual model is depicted in figure 23.

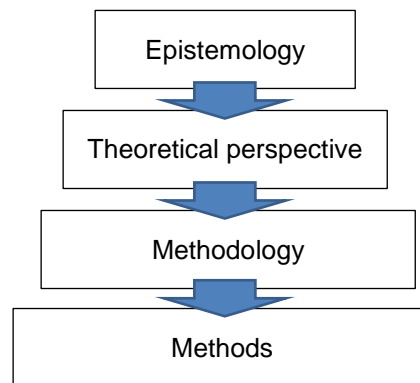


Figure 23 – Crotty's Research Methodology Model  
Crotty [214, p4]

Crotty depicts a four stage process starting with *epistemology*. He deliberately eschews including ontological elements because he contends that this causes confusion among researchers [214, p10]. Having made this point he then goes on to give examples of his epistemological positions – *objectivism*, *constructionism* and *subjectivism*. However, these are *ontological* terms (see section 4.1.2.1), so it appears Crotty is adding to the confusion he seeks to avoid.

Examples of the 'theoretical perspectives' stage of the model – include [214, p5]:

- Positivism (and post-positivism)
- Interpretivism
- Critical inquiry
- Feminism
- Post-modernism

So again there is some confusion here as these theoretical perspectives are a mix of other authors' epistemological terms and philosophical paradigms (see section 4.1.2.2 and 4.1.4). It will be seen in the following sections that the third and fourth stages of the model are more consistent with the other two models described with examples of methodology and methods listed in table 7.

Methodology	Methods
Experimental research	Sampling
Survey research	Measurement & scaling
Ethnography	Questionnaire
Grounded theory	Observation
Heuristic enquiry	Interview
Action research	Focus group
Discourse analysis	Case study
etc	Life history
	Statistical analysis
	Theme identification
	Cognitive mapping
	Interpretive methods
	Conversation analysis
	etc

**Table 7 – Crotty's Methodology & Methods Examples**  
Crotty [214, p5]

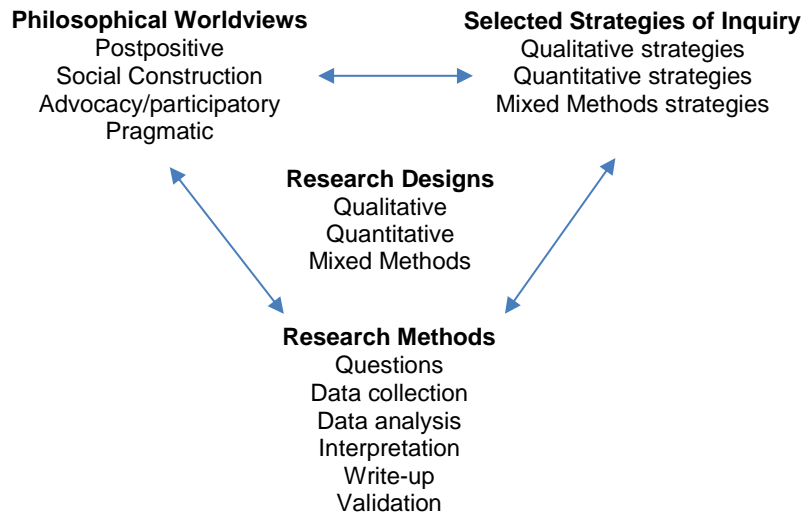
Crotty contends that there are clear rules as to which theoretical perspectives are appropriate for the epistemological position taken, but that after that link is made the choice of methodology and methods is effectively unconstrained [214, p12]. Crotty's model, with its lack of definition in its latter stages and inconsistent terminology compared to other authors, is surpassed in clarity and consistency by later research methodology models.

## 4.2.2 Cresswell's Framework for Research Design

The second research methodology model considered here is Cresswell's '*framework for research design*' shown in figure 24. Cresswell argues that there are three components that make up the research design – the philosophical worldview, the strategies of inquiry and the specific research methods [220, p5].

Philosophical worldviews have been discussed above in section 4.1.4. Strategies of enquiry are categorised by Cresswell as either quantitative, qualitative or mixed and the examples he cites [220, p12] reflect Crotty's list of methodologies in table 7.

Cresswell's research methods are similarly categorised and align with Crotty's list of methods in table 7.



**Figure 24 – Cresswell's Framework for Research Design**  
Cresswell [220, p5]

Cresswell argues that philosophical worldviews, research strategies and research methods all combine to result in a research design that *'tends to be quantitative, qualitative or mixed'* [220, p16]. The implication is that there is not necessarily a hierarchical or sequential series of decisions to take, but that the position in each of these four research aspects evolves iteratively until a logical, internally consistent position is achieved that also takes into account the nature of the research problem and the audience for whom the research outcome is intended [220, p18]. Cresswell proposes typical scenarios that result from such deliberations and these are shown in table 8.

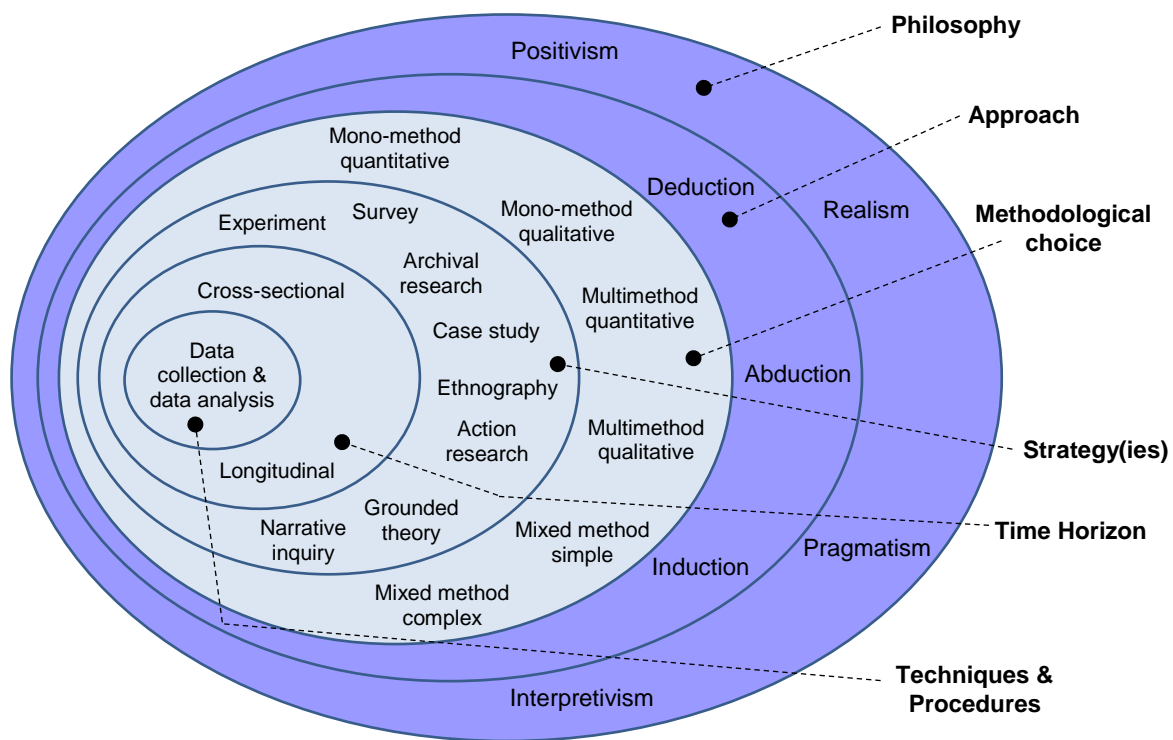
	<b>Qualitative</b>	<b>Quantitative</b>	<b>Mixed Methods</b>
Use these philosophical assumptions	Constructivist, advocacy/participatory	Post-positivist	Pragmatic
Employ these strategies of inquiry	Phenomenology, grounded theory, ethnography, case study, and narrative	Surveys and experiments	Sequential, concurrent, and transformative
Employ these methods	Open-ended questions, emerging approaches, text or image data	Closed-ended questions, predetermined approaches, numeric data	Both open- and closed-ended questions, both emerging and predetermined approaches, and both quantitative and qualitative data and analysis

**Table 8 – Cresswell's Research Design Approaches**  
Cresswell 2003 [220, p17]

Having seen Crotty’s four stage hierarchical research methodology model, followed by Cresswell’s three component, somewhat iterative approach, the third research methodology model reviewed here takes the most granular approach to moving from research philosophy to research design – Saunders’ Research Onion.

### 4.2.3 Saunders’ Research Onion

Saunders et al’s *Research Onion* is shown in figure 25.



**Figure 25 – Saunders’ Research Onion**  
Saunders et al [215, p128]

The research onion consists of six layers with research philosophy as its outer layer surrounding and providing the context for the other five layers. As each layer is considered and ‘peeled away’ the next stage of the journey towards the detailed research design in the centre of the onion is revealed for the researcher to deliberate. The diagram includes within each layer examples that may be selected by the researcher.

The research philosophy outer layer contains epistemological positions – positivism, realism, interpretivism and pragmatism (see sections 4.1.2 and 4.1.3). The next layer –

research approach – contains three examples: deduction, induction and abduction. These approaches are discussed in the next section (4.2.4).

Having established the research philosophy and approach, the remaining four layers of the research onion guide the researcher through overarching *methodological choice*, the specific nature of the research *strategy*, the *time horizon* of the research and finally the *techniques and procedures* to be employed. The examples presented in each of these layers in figure 25 correlate well with the other models discussed in this section.

Saunders et al's research onion model provides a structured and logically consistent way to organise a researcher's thoughts in justifying a philosophical position and the consequent research design. It will therefore be used in section 4.3 to describe the specific methodology that has been developed for this research.

#### 4.2.4 The Role of Theory in Research

Research includes the use of theory, and the role theory plays in the research will depend on the type of reasoning being employed by the researcher. Three types of reasoning are discussed here – deduction, induction and abduction.

*Deductive* reasoning involves the testing of a theory or a set of premises that have been developed by the study of extant literature [215, p143]. The conditions under which the theory is expected to be true are established so that a testable proposition (or propositions) is deduced. Data is collected to measure the concepts or variables. The subsequent analysis either disproves or corroborates the theory (Blaikie [221]). Key aspects of deductive reasoning include: a structured methodology to ensure results can be replicated; concepts and variables must be able to be measured (often quantitatively); results should be generalisable across the population from which the sample has been taken [215, pp145-6].

*Inductive* reasoning, by contrast, starts with data collection to explore an issue which then leads to theory (or theories) being developed to explain the nature of the problem [215, p145]. The benefit of this approach is that by investigating issues without the constraint of a pre-determined theory, nuanced effects caused by human idiosyncrasy can be properly taken into account that may otherwise be overlooked if taking a deductive approach [215, p146]. Typically small subject samples are used (when compared to the deductive approach) so that the context of the phenomenon can be explored fully using a variety of qualitative research methods [215, p147].

*Abductive* reasoning combines both deductive and inductive elements, iteratively moving between the two (Suddaby [222]). It starts with the observation of a 'surprising fact' to which the researcher then tries to fit a plausible theory (induction). The theory is then tested (deduction) [215, p147].

## 4.3 Research Methodology Development

This section describes the outcome of considering each layer of Saunders' onion from figure 25 in turn, with specific reference to the research that is the subject of this thesis. The first layer of Saunders' model is research philosophy.

### 4.3.1 Research Philosophy

This research considers the management and application of innovation in manufacturing businesses. The literature that has been reviewed in section 2 and upon which the hypotheses have been developed in section 3 is replete with concepts and frameworks that assume individual managers work within structures and adhere to procedures created for them by the organisations they work for. Furthermore, such structures and procedures are purported to be similar across businesses and industries. This viewpoint is ontologically firmly in the *objective* camp [215, p131].

It could be argued that a number of the topics discussed in the literature review are more *subjective* ontologically. For example the tendency for strategy development to be *emergent* rather than *deliberate* in nature, and the role individuals' decision biases play in their attitude to innovation. Here individual managers' interpretation of their responsibilities and the way their jobs should be done will have an impact at the local level. However the literature reflects on both these topics in a way that assumes individuals' behaviour is broadly predictable and that, in aggregate, will comply with generalised principles. Therefore this research remains ontologically *objective*.

In terms of the epistemological options offered in the philosophical layer of the onion model, this research takes a *positivist* approach. The relevant literature has been reviewed and a series of hypotheses have been developed that are to be tested. Data will be collected from observable reality, and correlations and causal relationships are to be examined in order to establish '*law-like generalisations*'. The research assumes



that the management area in question can be reduced to relatively simple concepts to aid examination and explication [217, p20].

The broader concepts of philosophical paradigms and worldviews add further colour to the pure ontological and epistemological positions (see section 4.1.4). Against Burrell & Morgan's typology [215, p141] this research falls into the *functionalist* category, where businesses are assumed to be rational and that solutions to organisational issues can be found within the boundaries of the current management systems and structure. In terms of Cresswell's worldviews [220, p6] this research is described by the *postpositivist* worldview where knowledge is created through making observations and measurements of the real world that are then used to support or refute a theory.

### 4.3.2 Research Approach

In this research the literature has been reviewed and a set of premises proposed. The premises will be tested using data collected from observable variables using a structured methodology to ensure results are generalisable. Deductive approaches are commonly, although not exclusively, allied with objective and positivist philosophies [215, p162]. The reasoning approach used in this research is therefore *deductive*.

### 4.3.3 Research Method

The third layer of Saunders' research onion is concerned with the methodological choice between quantitative, qualitative and mixed methods. Crotty suggests that researchers should avoid assuming that a particular philosophical standpoint automatically leads to a corresponding method, and observes that quantitative, qualitative and mixed methods can each be successfully used regardless of the philosophy in play [214, p15]. The more important issue according to Saunders (and Blumberg et al [217, p192]) is to ensure that there is a consistency of approach across philosophy, reasoning and the way the chosen research methods are used, the type of data they reveal and the conclusions that are drawn from the data.

Having made the point that there are no strict limitations on which research method can be employed in a given situation, there is guidance available as to which methods *tend* to be more appropriate and which are *typically* used in different scenarios. The literature review in chapter 2 has led to the development of the objective theories and

research objectives described in chapter 3. These require that correlation and causal relationship between variables are investigated. Concepts have been simplified (or reduced) to enable methodical analysis and to facilitate a general applicability of conclusions across relevant businesses.

Cresswell contends that quantitative research is:

*“... a means for testing objective theories by examining the relationship among variables. These variables, in turn, can be measured, typically on instruments, so that numbered data can be analysed using statistical procedures ... those who engage in this form of inquiry have assumptions about testing theories deductively, building in protections against bias, controlling for alternative explanations, and being able to generalize and replicate the findings.” [220, p4]*

Multi-method and mixed-method research options in this layer of the research onion are more suited to realism, interpretivism and pragmatism philosophies [215, p164]. The research method chosen for this research is therefore *mono-method quantitative*. The variables discussed in chapter 3 will be measured numerically and analysed statistically. This allows well-understood mathematical techniques to be employed that control for data validity and reliability [215, p162].

#### 4.3.4 Research Strategy

The objective of the research is to deduce and generalise results across the wider population of manufacturing businesses. A survey by questionnaire strategy is usually associated with a deductive approach [215, p176], and it does allow the collection of variable data from a relatively large sample of the relevant population which is important if generalisations across the population are to be inferred [220, p12]. Both objective (e.g. firm performance) and attitudinal (e.g. innovation propensity) variables are included in the research objectives and a survey questionnaire is appropriate for collecting both these types of data [215, p177].

The quantitative research methodology will therefore be delivered using a survey by questionnaire strategy.

### 4.3.5 Research Time-Horizon

The fifth and penultimate layer of the research onion is the time-horizon of the research. A single survey questionnaire elicits a cross-sectional study, a 'snap-shot', of the variables being considered. To achieve a longitudinal study multiple 'snap-shots' would be required over an extended time period which is not practically achievable given the time constraints of the research programme. The concepts and variables being examined in this research can be seen to have good temporal stability making a cross-sectional study appropriate in addressing the research objectives.

### 4.3.6 Research Techniques & Procedures

The final layer of Saunders' research onion is addressed in this section, which describes which techniques and procedures will be employed in delivering the research strategy and the theoretical justification for their use.

#### 4.3.6.1 New OF-AF Gap Measure

The first research objective is to establish a numeric measure of the distance between a manufacturing firm's operating and asset frontiers – its OF-AF gap. This is a new metric, or construct, in the literature.

The OF-AF gap measure is a latent – or unobservable – and continuous variable. Such variables can be assessed using a multiple, reflective-item scale (Boyd [223]). Multiple item scales measuring unobservable constructs lead to improved reliability and reduced measurement error than more simplistic approaches [223, p245]. Guidance for creating scales of this type with appropriate levels of reliability and validity can be found in the literature (e.g. Churchill 1979 [224], Hinkin 1995 [225], Boyd 2005 [223], Thompson 2009 [226], Saunders 2012 [215], Field 2013 [227]) and this guidance is broadly consistent and can be summarised as comprising four stages:

1. Generate content-valid items
2. Develop item scales
3. Purify the measure
4. Assess reliability & validity

The first step is to generate a number of measurable items, or variables, that capture the dimensions of the construct in question to its fullest extent [224, p67]. These variables are ultimately combined to create a single measure for the construct of interest. This research employs a deductive approach to scale development where a thorough review of the literature acts as a guide for the development of items [225, p969]. Incorporating similar but critically different elements results in a *'better foundation for the eventual measure'* [224, p68], however care must be taken not to incorporate *'obvious item duplication and overlap'* [226, p678]. Content validity is effectively being built into the measure through this process [225, p969].

It will be shown in chapter 5 how the list of items that form the OF-AF gap scale were deductively developed from the performance frontier literature discussed in chapter 2.

The second stage is to develop scales – i.e. groups of survey questions – for each item selected to form part of the OF-AF gap construct. This is graphically represented in figure 26, which shows 'n' items forming the new OF-AF Gap construct, with each item formed of question sets of varying length. The oval symbols represent *latent* (i.e. unobservable) variables and rectangular symbols represent *observable* (i.e. measurable) variables.

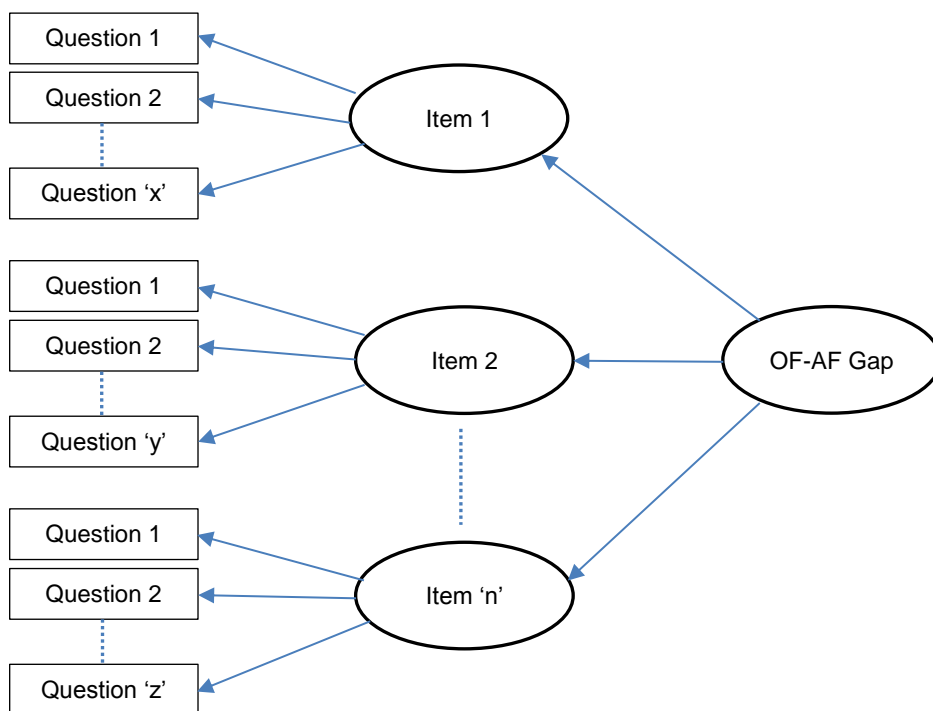
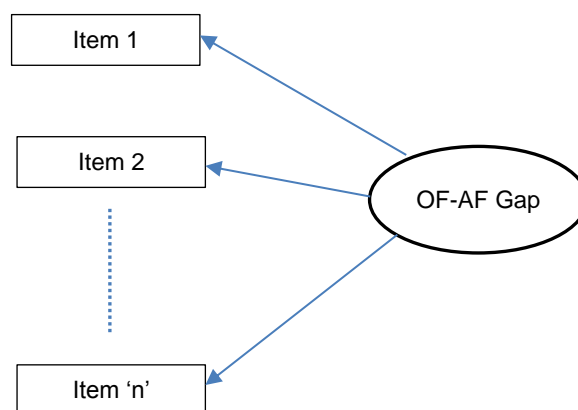


Figure 26 – OF-AF Gap Measurement Structure

In order to maximise the reliability of the overall construct, each of its constituent items will be measured using peer-reviewed survey instruments from the literature. Therefore the question sets for each item will have already been assessed for reliability and validity in their own right.

The diagram in figure 26 implies that the OF-AF Gap is a unidimensional latent variable, in that all items load directly onto it. However this may not be the case and the OF-AF Gap construct may consist of multiple latent factors – this cannot be predicted prior to survey analysis. If the OF-AF Gap construct does have multiple factors the structural equation model used for the analysis will have a complex hierarchy of latent variables which in turn would require large sample sizes to achieve acceptable model reliability. It is therefore proposed to numerically aggregate individual question responses for each question set to create a single numerical ‘answer’ for each respondent for each construct item. This is known as *parcelling* the data (Bandalos [228]) and leads to the simplified measurement structure shown in figure 27. In this scenario each item is now an *observable* (i.e. measurable) variable.



**Figure 27 – Simplified OF-AF Gap Measurement Structure**

Parcelling is a technique commonly used to simplify modelling and improve the reliability of analysis (Bandalos [228, p79]). Benefits cited for its use include that it provides useful approximations to continuous item scales, results in more stable and reliable analyses (Hagtvet & Nasser [229, p169]) and ameliorates the effects of any non-normality within item scales [228, p79]. Little et al [230, p155] also make the point that the reduction in model parameters that parcelling facilitates also reduces the required sample size to achieve acceptable model fit – see also section 4.3.6.6.

Parcelling should only be employed if the underlying scale for each item is unidimensional, but if this is ensured '*parcelling can be particularly effective*' (Little et al [230, p168]). When selecting items and the peer-reviewed survey instruments to measure them (in chapter 5) it will therefore be important to ensure unidimensionality.

The third stage of the construct creation process is to purify the measure following collection of survey responses. An initial check of Cronbach's coefficient of reliability (coefficient 'alpha' [231]) for each of the observable item scales will be undertaken. This should confirm the internal consistency (reliability) of those scales when used with this research's surveyed population.

Following this the structure of the OF-AF Gap construct will be investigated to determine if it is unidimensional or multifactorial. Cronbach's alpha could be used here to assess the internal consistency, or internal relatedness of the items, but it does not indicate their homogeneity, or unidimensionality (Panayides [232, p687]). In this scenario Exploratory Factor Analysis (EFA) is recommended to confirm unidimensionality and to characterise the nature of any latent factors [224, p69]. EFA is commonly used in refining constructs [225, p974] and Confirmatory Factor Analysis (CFA) should then be used to assess the *quality* of the factor structure [225, p976].

*"... the primary purposes of either exploratory or confirmatory factor analysis in scale construction are to examine the stability of the factor structure and provide information that will facilitate the refinement of a new measure ... Because of the objective of the task of scale development, it is recommended that a confirmatory approach be utilized. Exploratory techniques allow the elimination of obviously poorly loading items, but the advantage of the confirmatory ... analysis is that it allows the researcher more precision in evaluating the measurement model."* [225, p977]

EFA will be conducted using IBM's SPSS software and CFA by using IBM's AMOS structural equation modelling software. Goodness of fit indices will be as recommended by Byrne [233].

The final stage of the construct creation process is to assess the construct's reliability and validity. Hinkin contends that measures should demonstrate '*internal consistency*', '*content validity*', '*criterion-related validity*' and '*construct validity*'. [225, p968].

An **internally consistent** set of item scales results in a close correlation between individual item responses and the overall construct response [225, p968]. Cronbach's

coefficient of reliability (alpha) can confirm this for single factor constructs, while this approach is not appropriate for multiple factor constructs [227, p709]. For multiple factor constructs the item correlations to the overall measure should be assessed [227, p713].

**Content validity** (or content *adequacy* according to Schriesheim [234, p389]) *'refers to the adequacy with which a measure assesses the domain of interest'* [225, p968].

Blumberg states that the assessment of content validity is judgemental and is *'often intuitive and unique to each research designer'* [217, p450]. Churchill contends that *'specifying the domain of the construct, generating items that exhaust the domain, and subsequently purifying the resulting scale should produce a measure which is content or face valid and reliable'* [224, p70]. The first three stages of this process therefore ensure content validity.

**Criterion-related validity** considers how the measure behaves in relation to other independent measures [225, p968]. This will be assessed by examining the correlations and regressions that emerge between the OF-AF gap measure and the other main model variables – Environmental Turbulence, Firm Performance, Innovation Propensity & Emergent Strategy Bias. If the measure behaves in accordance with predictions from the literature – i.e. research hypotheses are supported – it can be said to have criterion-related validity.

Perhaps the most difficult to establish is **construct validity** which *'is concerned with the relationship of the measure to the underlying attributes it is attempting to assess'* [225, p968]. This is often established by comparing the new measure to other metrics designed to measure the same thing [224, p70]. This is problematic because researchers generally would not be trying to measure something that was easily measured in another way. Indeed Schriesheim contends that *'it may be an unrealistic pre-publication requirement to demand a full-scale attack on the construct validity of a new, previously untested ... measure'* [234, p389]. Saunders observes:

*"Researchers get round this problem by looking for other relevant evidence that supports the answers found using the questionnaire, relevance being determined by the nature of their research question and their own judgement."* [215, p429]

In terms of evidencing construct validity, Hinkin suggests that *'factor analytical techniques [can be used] to infer the existence of construct validity'* [225, p981] and that *'a stable factor structure provide[s] evidence of construct validity'* [225, p980].

Blumberg et al support this view [217, p452], while Anderson & Gerbring go further by commenting on the benefit of using structural equation modelling for confirmatory analysis:

*“The measurement model in conjunction with the structural model enables a comprehensive, confirmatory assessment of construct validity”* [235, p411]

So the proposed EFA and CFA approach that will be used will provide appropriate evidence of construct validity. Hinkin also contends that criterion-related validity itself allows the researcher to claim construct validity – ‘*to the extent that hypotheses using the measure are confirmed, confidence in its construct validity will be increased*’ [225, p980]. Indeed, as Thompson developed his new entrepreneurship metric the validation assessment stopped short of commenting directly on construct validity and concluded with criterion-related validity tests [226, p677 & 685].

A reliable and valid OF-AF Gap measure will therefore be considered to have been created if the following criteria are satisfied:

- Items selected to form the OF-AF gap construct are appropriately justified in the literature and cover the domain of the construct.
- Item scales are derived from peer-reviewed literature and are unidimensional.
- Survey responses to individual item scales have an internal reliability (Cronbach alpha > 0.7) reflecting consistency with their previous use in the literature.
- The construct is shown to have internal consistency by having:
  - A stable factor structure (not sensitive to EFA method applied)
  - A factor structure that conceptually aligns with the literature
  - A factor structure that is validated by CFA
  - Item scales adequately correlate with the overall construct score
- Criterion validity is established by appropriate correlation and regressions of the OF-AF gap measure with other model variables (i.e. hypotheses confirmation)

A final treatment of this new measure will be to establish a numerical norm for it as suggested by Churchill [224, p72]. This will be done by mathematically converting survey responses using the structure and regressions identified in the CFA model into a single numerical score. It is then possible to normalise this score to a 0-100 range. This will be useful in making comparisons between different groups and individual companies.



#### 4.3.6.2 Main Model Variables

In addition to the OF-AF gap latent variable there are four other *observable* variables in the hypothesis models of figures 20 & 21. They are *Environmental Turbulence*, *Business Performance*, *Innovation Propensity* and *Emergent Strategy Bias*. These variables will be measured using peer-reviewed survey instruments from the literature. Therefore the scale items within the observable variables will have already been assessed for reliability and validity in their own right. Individual question responses for each question set will be numerically aggregated in a similar manner to the OF-AF Gap item scales. The resulting variables will be checked for normality and reliability.

#### 4.3.6.3 Demographic Data

The survey instrument will include demographic questions to allow analysis of correlations between variables to be assessed across different respondent groups thereby facilitating a consideration of the general applicability of the research conclusions.

Where demographic, company and respondent data is collected, care has been taken in the data capture, analysis, transmittal and storage, not to breach the ethical standards required by the University. The text of the final survey instrument has been approved by the University of York's Ethics Committee.

#### 4.3.6.4 Pilot Survey

The survey instrument – which combines the item scales that make up the new OF-AF gap measure (section 4.3.6.1), the four main model variables (4.3.6.2) and the demographic data questions (4.3.6.3) – will be piloted using a sample of individuals from a single organisation. The purpose of the pilot is to check the format and operation of the survey and to, critically, assess the degree of consistency of answers from individuals at different seniority levels and of different disciplines.

The deployment of the pilot survey, the analysis of the responses and the implications for the main survey instrument are described in chapter 6.

#### 4.3.6.5 Main Survey

The deployment of the main survey is described in chapter 7 and the analysis of responses is presented in chapter 8. Exploratory Factor Analysis will be undertaken using IBM's SPSS software and Confirmatory Factor Analysis by using IBM's AMOS software.

Testing correlation hypotheses between the new OF-AF gap variable and the other four main model variables – i.e. those represented in figure 20 – will be assessed using bivariate correlations in IBM's SPSS software.

Testing causality hypotheses between the new OF-AF gap variable and the other four main model variables – i.e. those represented in figure 21 – will be assessed by creating a structural equation model (SEM) using IBM's AMOS software. Goodness of fit metrics will be as recommended by Byrne [233]. In contrast to SPSS's factor analytic model, AMOS's full latent (SEM) model allows the researcher to propose and model the regression structure between the latent variables and thereby test causality hypotheses [233, pp6-7]

#### 4.3.6.6 Survey Sample Size

There must be an adequate survey sample size for the statistical analyses to be valid and for conclusions to be sensibly drawn.

The minimum sample size to detect small-medium bivariate correlations ( $r = 0.25$ ) to achieve a two-tailed Type I error rate ( $\alpha$ ) of 0.05, and a Type II error rate ( $\beta$ ) of 0.2 – as recommended by Field [227, p70] – is **123** samples (calculated using a web-based tool [236]). Field also reports that a sample size of circa **150** is sufficient for the central limit theorem to apply, thereby removing constraints on data normality for significance testing [227, p172].

Hinkin asserts that an adequate sample size to undertake EFA, and CFA using structural equation modelling, is deemed to be of the order of **150** [225, p973]. Similarly Anderson & Gerbing [235, p415] and Gefen et al [237, p28] report sample sizes between **100** and **150** to be appropriate for structural equation modelling.

MacCallum et al contend that such generic guidance is too simplistic and that the characteristics of factors within the EFA and CFA models determine the acceptable minimum sample size [238, p90]. If 'high' communalities between factor loadings exist

then sample sizes as low as **60** can be adequate for robust and reliable analysis [238, p95]. This characteristic cannot be known prior to response analysis so caution must be taken in setting the target response level.

Having taken the above issues into account, this research aims to achieve total valid responses received from the main survey of circa **150**.

## 4.4 Chapter Summary

This chapter has described the theoretical underpinnings of research philosophy and discussed different approaches that can be taken to create valid and legitimate knowledge. The implicit philosophical assumptions associated with this research have been laid out and a model describing the process of moving from a particular philosophical standpoint through to detailed research design – Saunders ‘research onion’ – has been used to present the approach employed by this researcher.

This research has been shown to be ontologically *objective* and epistemologically *positive*. In seeking to analyse hypotheses that have been derived from an extensive literature review the research approach is *deductive*.

In order to examine the relationship between the variables in the hypotheses models of figures 20 and 21, a cross-sectional, quantitative survey instrument will be employed. The survey instrument will be designed to capture both the main model variables of *Environmental Turbulence*, *Business Performance*, *Innovation Propensity* and *Emergent Strategy Bias* as well as those items (or variables) identified to form the new construct of the *OF-AF Gap*.

Criteria for the successful creation of this new metric have been developed to ensure its reliability and validity.

A target sample size of 150 has been established from the literature which will guide survey target selection in chapter 7.

The next chapter, chapter 5, describes the implementation of the above research techniques and procedures in realising the actual research design.

# Chapter 5: Research Design

## 5.1 Introduction

This chapter implements the research methodology developed over the course of chapter 4. The research design process results in a survey instrument combining the item scales that make up the new OF-AF gap measure (section 5.2), the four other main model variables (5.3) and the demographic data questions (5.5).

Necessarily the majority of this chapter addresses the first two stages of the new construct development process described in section 4.3.6.1 – item generation (in section 5.2.2) and scale development (in section 5.2.3) – and how these stages are executed for the OF-AF Gap construct. Peer-reviewed measurement scales for the main model variables are selected in section 5.3 followed by consideration of the unidimensionality of all the selected scale items in section 5.4. Demographic questions are discussed in section 5.5, the sequence and format of the complete questionnaire is presented in section 5.6, and the chapter is summarised in section 5.7.

## 5.2 OF-AF Gap Construct

Prior to the first identified stage of the new construct development process – *item generation*, Churchill recommends that the domain of the construct within which items will be selected is carefully defined [224, p67].

### 5.2.1 Domain Definition

As discussed in section 2.3.8 of the literature review, Schmenner & Swink's *Theory of Performance Frontiers* describes two frontiers that characterise and constrain manufacturing performance [1]. The asset frontier is created by the investments made in physical equipment, plant and technology, while the operating frontier is set by the policies and procedures put in place by the operations management team given the suite of physical assets they have at their disposal [1, p108].

The first task of an operations management team is to ensure its actual operating position is as close to, if not at, its operating frontier. This operational improvement is

achieved through removing inefficiencies in its existing processes rather than any attempt to change *'the substance of either operating policy or physical assets'* [1, p109]. Having *improved* the operating position to be close to the operating frontier, further performance improvement can only be achieved by *betterment* of the operating frontier and moving it closer to the asset frontier. As the two frontiers converge the manufacturing unit is increasingly subject to trade-off considerations in terms of its competitive capabilities. This can only be relieved by investment in physical assets that re-establishes the gap between the two frontiers.

The *domain* of the new OF-AF Gap construct is the distance, or space, between the two frontiers. In order to fully characterise this domain and to select an appropriate set of items that will adequately combine to measure it, it is important to define from the literature the nature of the two frontiers in more detail.

Vastag contrasts the two frontiers by describing the asset frontier as being comprised of *structural* factors, whereas the operating frontier is comprised of *infrastructural* factors [7, p354]. Cai & Yang take a resource-based view and correlate structural factors to *tangible* resources and infrastructural factors to *intangible* resources [209, p132]. This creates the distinction between an asset frontier which is comprised of freely-traded resources, able to be replicated across industry competitors, and an operating frontier that is comprised of an inimitable, hard-won, unique resource set that can be the source of sustained competitive advantage for the firm.

In describing the construct domain there will both be structural/tangible factors that influence the *asset* frontier and therefore the frontier gap, and infrastructural/intangible factors that influence the *operating* frontier and therefore the frontier gap. A third source of potential items to include in the construct scale are proxy indicators for the OF-AF Gap itself based on the literature.

Based on operating and asset frontier definitions in Schmenner & Swink [1], Vastag [7], Boyer & Lewis [239], Cai & Yang [209] and their attendant discussion, the following areas define the domain of the OF-AF Gap construct and will be investigated for appropriate items to include in the measurement scale.

- Structural/tangible factors – facilities, technology, capacity, investment
- Infrastructural/intangible factors – workforce capability, planning, systems
- Indirect indicators of the OF-AF gap

These three areas are reviewed in the next section to identify items to be included in the OF-AF gap measurement scale.

## 5.2.2 Item Generation

Potential items from the three domain areas identified above, that could form part of the OF-AF Gap measurement scale, have been gleaned from the literature and are discussed below. At the end of each of the sections, specific items are selected for inclusion in the scale that cover the domain area adequately without undue duplication, and for which there is likely to be access to data measurement via a survey instrument (see also section 4.3.6).

### 5.2.2.1 Structural/Tangible Factors

Four structural factors are considered for inclusion: asset utilisation, age of assets, asset investment, and process slack.

#### **Asset Utilisation**

Vastag directly interprets the distance between the operating and asset frontier as a firm-specific 'asset utilisation' – that is, how much of the potential provided by the assets is being exploited in practice [7, p357]. He likens the asset frontier to a *design* capacity, and the operating frontier to an *effective* capacity once the organisation's policies and systems are overlaid [7, p354].

Care must be taken not to conflate this performance frontier definition of 'asset utilisation' with more traditional operations metrics such as *capacity utilisation*. Capacity utilisation is typically employed to measure *quantity* of output against a theoretical maximum for the plant or process in question. Asset utilisation in the context of performance frontiers considers the utilisation of the assets across a range of dimensions, or capabilities, that the asset can potentially bring to the organisation – not just numerical output [7, p354].

However, the traditional output-centric definition of asset utilisation is a legitimate sub-component of the wider performance frontier definition, and hence a suitable scale item measure for the OF-AF Gap construct. Lapré & Scudder [205], Ramdas & Williams [206] and Nand et al [207] have all used asset utilisation in this way as a means to measure the OF-AF gap. However, this extant literature has only applied asset utilisation for OF-AF gap measurement to the aircraft industry – so a more general metric will need to be used for wider applicability. Vastag contends that the greater the asset utilisation, the smaller the OF-AF Gap [7, p354].

## **Age of Assets**

Vastag describes the phenomenon of the operating frontier moving incrementally closer to the asset frontier over time as staff ‘master their assets’ [7, p358]. This is supported by Power [210] who describes how the operating frontier and asset frontier converge as asset investments mature:

*“... as investment in structure (physical assets) is accompanied by investment in infrastructure (methods and systems), and both mature over time, it is proposed that operations and asset frontiers will converge and limit incremental investment returns.”* [210, p1185]

This idea of diminishing investment returns as frontiers converge and performance plateaus is built on by Knott et al [240] and Teece [134] who contend that far from simply plateauing, the assets’ technological value to the firm erodes over time as new technology gradually makes them obsolete.

*“By jettisoning ‘dead’ or dying assets, the enterprise is no longer shackled with an asset base that can be a crutch and provide a false sense of security, and sustain groups inside the enterprise that persist in torpedoing new initiatives. In abandoning dead or dying assets, the enterprise frees itself of certain routines, constraints, and opportunities for undesirable protective action inside the enterprise.”* [134, p1333]

An aggregate age of assets metric is therefore a suitable scale item measure for the OF-AF Gap construct. The older the assets on average the smaller the OF-AF gap because organisations naturally, and incrementally, improve processes and systems to drive better performance out of their assets over time.

## **Asset Investment**

Cai & Yang [209] contend that the asset frontier can be enumerated by considering the level of investment that has been made in facilities and equipment:

*“... we maintain that a firm's asset frontier could be reflected by the investment it has already made in facilities and labour forces, as well as the resources available for implementing operational strategies. These factors determine the maximum possible output the firm may achieve.”* [209, p136]

It is therefore likely that the level of asset investment will correlate with the position of the asset frontier. However, the asset frontier will have been created as a result of investments over many years and it is the age profile of these investments that is critical – if the investment is loaded into more recent years then the asset frontier is likely to extend beyond the operating frontier by a greater degree. Obtaining sensible estimations of asset investments over a reasonable time period (say 10 years) via a survey instrument does not seem likely.

The age of assets item scale discussed above is a reflection of the level of asset investment and does incorporate the age profile of those investments. It is more likely respondents will be willing and able to answer questions about the age profile of a set of assets, rather than provide monetary estimates of asset investments over an extended period.

### **Process Slack**

Schmenner & Swink [1] identify that the ratio of an organisation's products' throughput time relative to its processing time is a measure of process 'slack'. The more slack there is indicates that physical assets are underutilised – possibly suffering from bottlenecks – and the further from the asset frontier you must be:

*“For example, a possible indicator of nearness to the [asset] frontier is the ratio of throughput time and processing time for the plant's products.” [1, p111]*

A ratio of 1:1 is perfection, but even a ratio as low as 2:1 is considered by many as 'world class', when this represents only 50% utilisation [1, p111]. Reducing the non-processing element of throughput time improves the asset utilisation and reduces the OF-AF Gap through 'betterment' of the operating frontier.

To enumerate an overall process slack position for an organisation, an assessment would need to be made across all product types serviced by the manufacturing unit. Each product would place different demands on the physical assets resulting in different product slack positions. This subtlety would be difficult to access and appropriately aggregate across different manufacturing businesses via a survey instrument. This potential scale item certainly overlaps, and to a certain extent duplicates, the asset utilisation item above.



From the group of four structural factors, *asset utilisation* and *age of assets* will be taken forward for inclusion in the OF-AF Gap set of scale items. *Asset investment* and *process slack* will be discarded at this stage due to their underlying similarity to the two items that *will* be used, and the difficulty associated with accessing appropriate metrics using a survey instrument.

The next two sections – 5.2.2.2 and 5.2.2.3 – review infrastructural factors in two groupings; those that broadly relate to organisational and workforce capability and those that cover the application of new knowledge

### 5.2.2.2 Infrastructural/Intangible Factors – Capabilities

Four infrastructural factors related to organisational and workforce capability are considered here: continuous improvement, training, competence, and quality.

#### **Continuous Improvement**

In parallel and in a similar manner to the phenomenon of asset erosion discussed above under *age of assets*, an organisation's capabilities will naturally erode over time:

*“A company that adopts a capabilities-based approach to operations strategy has to commit itself to continual improvement because capabilities are ephemeral – they wither if not used, and become obsolete if not continually nourished and reinforced.”* (Hayes & Pisano [165, p34])

Businesses are therefore encouraged to continually improve processes and systems to maintain competitive capabilities. Timenes Laugen et al [241] observe that ‘traditional’ best practice improvement initiatives focussed around IT and quality are now seen as ‘a given’ in high performing manufacturing businesses and that the focus has moved on to other initiatives including pull production and equipment productivity which impact higher order capabilities such as reliability [241, p144].

Such improvement activities involve refinement of processes and systems in the pursuit of bettering the operating frontier. If a firm exhibits significant continuous improvement activities there must be ‘room’ between the operating frontier and the

asset frontier for these initiatives to effect this betterment. Indeed, Rosenzweig & Easton [242] contend that:

*“... the existence of substantive performance-enhancing initiatives would contradict the assumption that the manufacturer is close to the asset frontier...”* [242, p131]

Cai & Yang also link business and process improvement initiatives to the betterment of the operating frontier [209, p136]. Continuous improvement activity in an organisation should therefore be a component of the OF-AF Gap construct. Higher levels of continuous improvement indicate a larger OF-AF Gap.

### **Training**

Workforce training can also be an indicator of the gap between the operating and asset frontiers, in two different contexts. Firstly, associated with the continuous improvement initiatives discussed above. Very often such initiatives are accompanied by complementary workforce training. Secondly it is also associated with the deployment of new physical assets. Chung & Swink [204] make reference to this in their discussion of the effect of introducing Advance Manufacturing Technology (AMT):

*“Utilisation of AMT’s, reinforced with enhanced process knowledge, allows a plant to distance itself from its former asset frontier.”* [204, p535]

Where training is associated with continuous improvement, there must be sufficient space between the frontiers for the training to have the effect of improving performance, and where training is associated with new asset deployment the distance between frontiers is being widened by that deployment. The corollary of this contention is that if there is minimal OF-AF Gap then it is likely that the workforce has ‘mastered its assets’ [7, p358] and no training is required. Higher levels of workforce training therefore indicate a larger OF-AF Gap.

### **Competence**

Power [210] distinguishes between a manufacturing unit’s competence and capabilities by asserting that *“competence represents what you can do, while capability is what you*

*have the potential to do, and that capability builds on a base level of competence”* [210, p1187]. So as the business aspires to extend its capabilities and correspondingly improve the position of its operating frontier, the competence of its staff will need to be elevated accordingly.

Building manufacturing competences in support of the strategic objectives of the firm have long been encouraged (for example Hayes & Pisano [180, p81], and Swink & Hegarty [184, p375]). More recently it has been recognised that managers must invest to ensure competences fit *‘both current and known market requirements as well as future and unpredictable market requirements’* (Brown & Blackmon [8, p801]), inferring the need to build a suite of skills, not all of which will be immediately required.

Spring & Boaden [168] take this further and make the link directly between competence building and asset accumulation:

*“Competences act as ‘catalysts to asset accumulation’ ... strategy no longer means selecting the ‘right’ process technology and production planning system for the selected competitive criterion, but also involves developing the competences that enable quicker, cheaper asset accumulation”* [168, p774]

A manufacturing unit where competences are not static, but are being developed and enhanced, will maintain a rate of asset accumulation that will prevent the operating and asset frontiers converging. The rate of change of manufacturing competencies should be an indicator of the distance between the operating and asset frontiers.

Measuring the rate of change of competence via a survey instrument will be challenging. However, this infrastructural dimension can be effectively assessed by combining both the continuous improvement and training dimensions previously discussed.

### **Quality**

Quality as a competitive capability is the base layer of Ferdows & De Meyer’s sand-cone model [190], and as such is the first capability to be addressed in many firms [241, p144]. It may be that this capability is therefore relatively static in such organisations.

However, developing and extending quality performance does form a component of the operating frontier, and indeed Cai & Yang incorporate quality into their measurement of the operating frontier [209, p144]. Consequently it can be considered to influence the distance between the operating frontier and asset frontier.

Theoretically at least, a firm's effective quality at the operating frontier could be compared with the quality that could be achieved if the assets available were fully exploited – thereby inferring a magnitude of the OF-AF Gap. Practically, though, the concept of measuring the 'achievable level' of quality at the asset frontier is a somewhat abstract idea and data would be difficult to extract via a survey instrument.

Quality objectives usually form a critical component of continuous improvement initiatives, so it can be argued that by assessing continuous improvement activity, quality is being appropriately considered.

From this group of four infrastructural factors, *continuous improvement* and *training* will be taken forward for inclusion in the OF-AF Gap set of scale items. *Competence* and *quality* will be discarded at this stage due to the difficulty associated with accessing appropriate metrics using a survey instrument.

### 5.2.2.3 Infrastructural/Intangible Factors – New Knowledge

Three infrastructural factors related to the application of new knowledge are considered here: absorptive capacity, ambidexterity and innovation life cycles.

#### **Absorptive Capacity**

Absorptive capacity was reviewed in the literature review section 2.3.4, and this organisational dimension is given importance by the assertion that firms need '*prior related knowledge to assimilate and use new knowledge*' (Cohen & Levinthal [147, p129]). Leonard-Barton [123] underlines the difficulty of assimilating new knowledge – even if that knowledge is readily accessible:

*“Even if the technological knowledge can be accessed from outside, however, tremendous management effort is required to nurture that initial outlay into an enabling or core capability.” [123, p155]*

Lane et al’s model presented in figure 8 [149, p856] shows that absorptive capacity consists of three key elements; recognising and understanding new knowledge, assimilating valuable external knowledge and applying valuable external knowledge. All three of these aspects combine to improve both the firm’s ability to envisage future technical advances and its capability to exploit them.

As has been discussed, betterment of the operating frontier can be achieved through continuous improvement activities. Extending the asset frontier through technology and/or equipment acquisition, however, requires the organisation to have a level of absorptive capacity to understand, assimilate and apply the new outside knowledge that is associated with the investment. Indeed, Patel et al report that higher levels of absorptive capacity ensure firms are *‘better able to implement new manufacturing practices’* and *‘can better respond to technological innovations’* [195, p204].

Furthermore, these enhanced abilities lead to practical outcomes:

*“... firms with high levels of absorptive capacity are more likely to understand how to perform innovation activities related to new product and process implementation.” [195, p204]*

Liu et al confirm the contention that absorptive capacity creates space between the operating and asset frontiers as it *‘increases the level of manufacturing slack’* [193, p1258]. The ability to both understand and apply new knowledge draws on both parts of Zahra & George’s 2002 [151] conceptualisation of absorptive capacity shown in figure 9 – firms must exhibit both *potential* and *realised* absorptive capacity in order that the asset frontier is propelled forward.

Lane et al [149, p844] and Tu et al [243, p693] observe that the principal focus for many years has been on absorptive capacity as it pertained to the R&D function. Clearly, for this study a more operations-based measurement is required. Patel et al [195, p202] propose the term *operational absorptive capacity*. Higher levels of operational absorptive capacity therefore indicate a larger OF-AF Gap.

## **Ambidexterity**

Ambidexterity was reviewed in the literature review section 2.2.4.1, where the challenges of balancing exploitative and explorative activities – thereby being ambidextrous – were discussed. It has been shown that the goal of simultaneously realising exploitation and exploration is difficult, but necessary to ensure business viability in both the short and long term (Levinthal & March [64, p105]).

He & Wong [244, p482], Atuahene-Gima [99, p80] and Bierly et al [245, p486] recognise that resource allocation is at the heart of the issue as firms find it easier to reinforce relatively short-term exploitative successes, while the more uncertain, explorative activity is more difficult to ‘sell’ within the business.

Wang & Rafiq [246, p60] observe that ambidexterity requires operational ‘slack’, resources available to devote to two distinct types of developmental activities. An organisation that consciously fosters an environment that encourages ambidextrous behaviour will be able to pursue both incremental and more radical innovations at high levels of operational efficiency (Kortmann et al [247, p483]), making the most of the resources deployed.

The two ambidexterity elements will influence the manufacturing unit’s performance frontiers in different ways. Exploitative activity is focussed on the refinement of existing processes and systems, to yield improved results from essentially the same assets that has a history of performing well – effectively bettering the operating frontier. Explorative activity, on the other hand, is *‘intended to respond to and drive latent environmental trends by creating innovative technologies’* (Lubatkin et al [84, p648]) – effectively extending the asset frontier.

The effect of exploitative activity on the operating frontier can be considered in isolation, in that no explorative component is required to facilitate the frontier’s betterment. The same is not true for the effect of explorative activity on the asset frontier. Exploration, without an accompanying exploitation component, often leads to unfulfilled, and ultimately disruptive exercises in technological search and experimentation [244, p482]. Explorative activities cannot take root without an appropriate level of internal operational competence that is built by exploitative activities.

*“... a firm that is too oriented toward exploration suffers the costs of experimentation without gaining many of its benefits because it exhibits too*

*many new and risky ideas and little refinement of its existing competencies.” [99, p65]*

Therefore, to assess the influence of ambidexterity on the distance between the operating and asset frontiers, there are two aspects to consider. Firstly, the degree to which exploitation *dominates* exploration, reflecting the betterment of the operating frontier and the closing of the OF-AF Gap. Secondly, the *balance* of exploration and exploitation activity to reflect the extension of the asset frontier out in front of the operating frontier.

If exploitation *dominates* exploration, excessive development of competences with existing tools will occur leading to diminishing returns for the firm’s efforts, and a developmental inertia sets in – a competency trap – that inhibits appropriate responses to external stimuli (Simsek et al [73, p867] and Patel et al [195, p204]). The operating frontier will have been bettered through process improvement but the asset frontier will be static because new products and technologies will have been neglected (Tamayo-Torres et al [196, p6177]). The OF-AF gap in this situation will be smaller.

The second aspect to consider is ambidexterity *balance*. It is important that both ambidexterity components are adequately represented. Hill & Birkinshaw show that high levels of both explorative and exploitative activities lead to higher levels of breakthrough innovations and investment in disruptive technologies [248, p C3]. This infers significant extension of the asset frontier, creating a larger OF-AF Gap.

So to account for the need for exploitation and exploration balance, a measure to assess their congruence will be needed – the greater the *congruence* (i.e. smaller the difference) between the two, the larger the OF-AF Gap. Patel et al [195] refer to this measure as *operational ambidexterity*.

Ambidexterity will therefore contribute two item scales to the OF-AF Gap construct: *exploitation domination* and *operational ambidexterity*.

### **Innovation Life Cycles**

Innovation life cycles were reviewed in section 2.2.2. The rates and phasing of innovation in products and process were discussed as well as the maturity of technologies within an organisation. It is clear that the demands placed on the operating frontier by the product mix (Vastag [7, p355]) will alter depending on the

'newness' of the products and the technologies required to produce them. Investments in new assets are often timed to suit individual product launches rather than an overarching strategic plan [175, p378] (see also section 2.3.6.2).

Operational competences that form an integral part of the operating frontier also follow life cycles. However, Helfat & Peteraf [249] contend that:

*"Along their evolutionary paths, capabilities may support a sequence of products or multiple products simultaneously. Thus, a product lifecycle and the lifecycle of the core capabilities from which the product springs do not have a one-to-one correspondence. In addition, because resources and capabilities are fungible across products, the lifecycle of a typical capability may extend beyond that of a typical product. A capability also may pass through multiple stages of transformation before it faces an ultimate decline."* [249, p998]

So this creates a degree of detachment between individual product innovation cycles and manufacturing technology innovation life cycles. They are related in that new products require adequate technology for them to be made, but manufacturing technology life cycles often cover multiple product life cycles in order to reap adequate return on the asset investment. As a technology life cycle matures, capabilities and systems incrementally develop until the asset frontier is approached. Rosenzweig & Roth describe the situation *'at the end of an innovation cycle as manufacturing approaches the performance frontier, operating systems become technologically constrained'*, and when this happens organisations face diminishing returns on investments in incremental developments of existing processes [203, p356]. Liu et al [193] reinforce this view:

*"... manufacturing practices may extend an innovation cycle enabling the firm to better exploit its manufacturing operations. Over time, however, manufacturing processes may yield diminishing returns and require new assets, such as acquiring new technologies that will loosen the constraints [manufacturing business units] will experience as their capabilities evolve closer to their performance frontiers."* [193, p1256]

Therefore, if it was possible to measure the point at which an organisation was in its technological and/or innovation life cycle, this would be an indication of the space between an organisation's operating and asset frontiers – the more mature the position



in the life cycle, the less space between the two frontiers. However, many organisations will have, at a point in time, several manufacturing technologies at different stages in their life cycle. These asset and resource combinations will be unique to each firm, and will have evolved to suit the product mix and new product development programme that they are designed to support.

Measuring a reasonable aggregate position for the maturity of innovation life cycle(s) in an organisation would be difficult for most survey respondents as this is potentially quite an abstract concept. Innovation life cycle maturity is, to some extent, obliquely addressed through the age of assets and ambidexterity item scales discussed above. Innovation life cycles will therefore not be taken forward as an independent item to form part of the OF-AF gap construct.

From this group of three infrastructural factors, *operational absorptive capacity* will be taken forward for inclusion in the OF-AF Gap set of scale items, as well as two distinct aspects of ambidexterity – *exploitation domination* and *ambidexterity congruence*. *Innovation life cycles* will be discarded at this stage.

#### 5.2.2.4 Indirect Indicators

Three potential indirect indicators of the OF-AF Gap are considered here: manufacturing flexibility, product portfolio complexity and asset orchestration.

##### **Manufacturing Flexibility**

Upton defines manufacturing flexibility as “*the ability to change or react with little penalty in time, effort, cost or performance*” [250, p73]. Flexibility in this sense forms one of the four competitive capabilities – quality, dependability, flexibility and cost – that are regularly cited in the operations literature and were reviewed in section 2.3.7.

Ferdows & De Meyer’s 1990 sand cone model [190] and Roth’s 1996 competitive progression theory [192] (reviewed in section 2.3.7.2) suggest that simultaneous high performance on the four key competitive capabilities can only be achieved by progressive development of each capability in a prescribed order. Flexibility is developed in the latter stages of this process and so can be considered a ‘higher-order’

capability. Indeed, in the work that originally stimulated Ferdows & De Meyer, Nakane put flexibility at the top of the pile [251].

Schmenner & Swink [1] and Vastag [7] contend that these capabilities cannot be built cumulatively and without trade-off if the operating frontier is close to the asset frontier, and Rosenzweig & Easton support this by stating that *“initiatives that improve performance along multiple dimensions simultaneously should not be readily available to manufacturers on or near the asset frontier”* [242, p131].

Firms that exhibit the higher-order manufacturing capability of flexibility are therefore operating further from their asset frontier. Chung & Swink reflect this correlation in their analysis of the deployment of advanced manufacturing technology – asset frontiers are extended facilitating the development of operational flexibility [204, p541].

Higher levels of manufacturing flexibility indicate a larger OF-AF Gap.

### **Product Portfolio Complexity**

The complexity of an organisation’s product portfolio will place varying demands on the manufacturing assets available to produce them. Different products will require different levels of capability from the suite of production assets owned by the firm. Furthermore, product mix can change instantly as sales demands fluctuate, thereby suddenly changing the capability demands on the production equipment. Some product mixes will ‘utilise’ the assets more fully than others.

As discussed in section 2.3.8, Vastag recognises the fact that the product mix will affect the distance between the operating and asset frontiers [7, p356]. More recent discussion by Jacobs & Swink [208] concur with Vastag that the theory of performance frontiers may

*“... therefore be useful as a means for explaining [product portfolio complexity’s] effects on operational performance vis-à-vis an organisation’s current operating position relative to its asset frontier – its current utilisation”* [208, p687]

Different product mixes create different operating frontier profiles against the organisation’s asset frontier. The different asset utilisations for the product mixes infer that some mixes require the operating frontier to be closer to the asset frontier than do

others. The more complex the product portfolio the wider spread of effect on the operating frontier will be exhibited, and the further the aggregate position of the operating frontier will be from the asset frontier.

Put another way, with a more complex product portfolio the greater distance is required between the operating frontiers to cater for the variances in capability demanded by their production.

Higher levels of product portfolio complexity indicate a larger OF-AF Gap.

### **Asset Orchestration**

Asset orchestration was reviewed in section 2.3.3. Sirmon et al [136, 137, 139] and Helfat et al [138] present asset orchestration as a dynamic organisational capability that enables firms to reconfigure and leverage existing assets to both extract the maximum utilisation from the assets and to effectively respond to environmental turbulence.

Li et al [140] make the link between effective resource orchestration and the ultimate strategic flexibility of the organisation. Using this dynamic capability effectively will improve operating capabilities (Teece [120]), effectively moving and reshaping the operating frontier within the limits defined by the asset frontier.

It is reasonable to conclude that the more effective a firms' asset orchestration efforts are, then the closer the operating frontier will be to the asset frontier. However, both Sirmon and Helfat's orchestration constructs [138, 139] intimately link orchestration activities with asset investment and acquisition. Therefore, even if it was possible to effectively measure the degree of an organisation's orchestration capability it would inevitably be an insufficiently pure measure and would be contaminated by the investment and acquisition elements of Sirmon and Helfat's constructs.

Asset orchestration in this form will therefore not be included as a scale item for the OF-AF gap construct.

From this group of three infrastructural factors, *manufacturing flexibility* and *product portfolio complexity* will be taken forward for inclusion in the OF-AF Gap set of scale items. *Asset orchestration* will be discarded at this stage.

### 5.2.2.5 OF-AF Gap Item Selection Summary

The nine items shown in table 9 have been selected from the four sections above for inclusion in the OF-AF construct.

Group	Item	Expected Polarity
Structural Factors 5.2.2.1	Asset Utilisation	Less utilisation – larger OF-AF gap
	Age of Assets	Younger assets – larger OF-AF gap
Infrastructural Factors – Capabilities 5.2.2.2	Continuous Improvement (CI)	More CI – larger OF-AF gap
	Training	More training – larger OF-AF gap
Infrastructural Factors – New Knowledge 5.2.2.3	Operational Absorptive Capacity (AC)	Higher AC – larger OF-AF gap
	Exploitation Domination	Less domination – larger OF-AF gap
	Operational Ambidexterity	Smaller difference – larger OF-AF gap
Indirect Indicators 5.2.2.4	Manufacturing Flexibility	More flexibility – larger OF-AF gap
	Product Portfolio Complexity	More complexity – larger OF-AF gap

**Table 9 – OF-AF Gap Item Selection Summary**

The nine items adequately cover the domain of construct by addressing the structural and infrastructural factors highlighted in the literature (see section 5.2.1). Peer-reviewed question sets for these nine scale items will be sourced from the literature in the next section.

### 5.2.3 Scale Development

For each of the OF-AF Gap construct scale items selected in section 5.2.2, peer-reviewed question sets are required to elicit responses from survey respondents. Consideration must be given to the applicability of questions to a wide range of industry sectors, and the ability of individual respondents to effectively answer questions across a range of topics. Potential sources for each scale item question set are discussed below.

### 5.2.3.1 Asset Utilisation

From section 5.2.2.1 above, a measure of traditional, output-centric asset utilisation is required. The framing of the question must be generally applicable across multiple industries. An estimation is required of the degree to which an organisation's current effective capacity can be increased before the asset frontier comes into play and disproportionately raises production costs.

Tipper et al [252] reference the New Zealand Institute of Economic Research's *capacity utilisation business opinion* index, and this approach closely fits the requirement of this research. The index is created by respondents answering a single question:

*"Excluding seasonal factors, by how much is it currently practicable for you to increase your production from your existing plant and equipment without raising unit costs?"* [252, p13]

A five-category ordinal scale is used for responses: 0%, 1–5%, 6–10%, 11–20% and over 20%. The index is then calculated by setting actual output equal to 100 and dividing by the capacity output – 100 plus the median value of spare capacity [252, p13]. The corresponding ordinal utilisation values will therefore be 100%, 97.1% (100/103), 92.6% (100/108), 86.6% (100/115.5) and 80% (100/125) respectively.

### 5.2.3.2 Age of Assets

It is not likely that many survey respondents will have access to detailed asset schedules, or be motivated to consult them. Therefore an *estimation* of the aggregate age of assets for each firm will be sought. This approach has several precedents in the literature, for example Klassen [253, 254]. Schmenner & Rho [255] describe a method whereby respondents are asked to estimate the percentage of equipment which falls in various age categories. McKone et al [256] describe the approach in detail and this will be adopted in this research. McKone et al's approach begins by asking the question:

*"Roughly what percent of the equipment in this plant falls into each of these age categories?"* [256, p141]

<i>Less than 2 years old</i>	<i>(1)</i>
<i>3-5 years old</i>	<i>(4)</i>
<i>6-10 years old</i>	<i>(8)</i>
<i>11-20 years old</i>	<i>(15.5)</i>
<i>Over 20 years old</i>	<i>(25)</i>

Respondents are constrained to allocate exactly 100% across the five categories. The estimated aggregate equipment age is then derived by calculating a weighted average using the median age shown in parentheses as the weighting for each category.

### 5.2.3.3 Continuous Improvement

There are multiple examples in the quality management literature for measuring continuous improvement in manufacturing businesses by survey. These range in complexity from single question enquiries (e.g. Puvanasvaran et al [257]), through grouped question sets (e.g. Jabnoun & Sedrani [258] and Yang et al [259]) up to complete self-assessment tools (e.g. Caffyn [260]). The question set selected was used in Peng et al [182] and consists of five questions, with responses graduated across a 7-point Likert opinion scale ranging from 'strongly disagree' to 'strongly agree':

1. *We strive to continually improve all aspects of products and processes, rather than taking a static approach*
2. *We search for continued learning and improvement, after the installation of new equipment*
3. *Continuous improvement makes our performance a moving target, which is difficult for competitors to attack*
4. *We believe that improvement of a process is never complete; there is always room for more incremental improvement*
5. *Our organization is not a static entity, but engages in dynamically changing itself to better serve its customers*

### 5.2.3.4 Training

The amount of training a workforce enjoys can relatively easily be numerically assessed. An example of this is found in Abdel-Maksoud et al [261] where respondents are asked to indicate the average days per year that shop floor workers receive formal training in the following groupings:

- Less than 1 day
- 1-2 days
- 3-5 days
- 6-10 days
- 11-30 days
- More than 30 days

This numeric approach may not yield comparable results across different industries where training norms are likely to be different. It is therefore proposed to use a reflective scale to indicate the level of training instead. This will be realised by asking the respondent to assess the degree of organisational learning that has occurred over the preceding period – a more all-encompassing view of employee training.

Tamayo-Torres et al [196] measure organisational learning using the following four questions, with responses graduated across a 7-point scale ranging from 'strongly disagree' to 'strongly agree'.

1. *The organisation has learned or acquired much new and relevant knowledge over the last three years.*
2. *Organisational members have acquired critical capacities and skills over the last three years.*
3. *The organisation's performance has been influenced by new learning it has acquired over the last three years.*
4. *The organisation is a learning organisation.*

### 5.2.3.5 Operational Absorptive Capacity

As shown in section 5.2.2.3, this scale item should measure *operational* absorptive capacity as defined by Patel et al [195] – that is the sum of potential absorptive capacity and realised absorptive capacity.

There are numerous measurement instruments designed to capture aspects of absorptive capacity, for example, Lichtenthaler [150], Fernhaber & Patel [262], Najafi et al [263] and Su et al [154]. Many of these are in fact just derivations of Jansen et al's 2005 question set [264], which itself is closely linked to Zahra & George's 2002 seminal absorptive capacity publication [151].

Cepeda-Carrion [152] also sources its questions from Jansen et al, and it is Cepeda-Carrion's question set that will be used for this research. The questions are grouped into two sections covering potential absorptive capacity and realised absorptive capacity respectively, with responses graduated across a 7-point scale ranging from 'strongly disagree' to 'strongly agree'.

### **Potential Absorptive Capacity**

1. *Our unit has frequent interactions with corporate headquarters to acquire new knowledge*
2. *Employees of our unit regularly visit other branches*
3. *We collect industry information through informal means*
4. *Other divisions of our company are rarely visited (reverse scored)*
5. *Our unit periodically organises special meetings with customers or third parties to acquire new knowledge*
6. *Employees regularly approach third parties such as accountants, consultants or tax consultants*
7. *We are slow to recognise shifts in our market (e.g. competition, regulation, demography) (reverse scored)*
8. *New opportunities to serve our clients are quickly understood*
9. *We quickly analyse and interpret changing market demands*

### **Realised Absorptive Capacity**

1. *Our unit regularly considers the consequences of changing market demands in terms of new products & services*
2. *Employees record and store newly acquired knowledge for future reference*
3. *Our unit quickly recognises the usefulness of new external knowledge to existing knowledge*
4. *Employees rarely share practical experiences (reverse scored)*
5. *We work hard to seize the opportunities for our unit from new external knowledge*
6. *Our unit periodically meets to discuss consequences of market trends and new product development*
7. *It is well known how activities within our unit should be performed*
8. *Client complaints fall on deaf ears in our unit (reverse scored)*
9. *Our unit has a clear division of roles and responsibilities*
10. *We constantly consider how to better exploit knowledge*
11. *Our unit has difficulty implementing new products and services (reverse scored)*
12. *Employees have a common language regarding our products and services*



### 5.2.3.6 Exploitation Domination

This scale item and the one that follows in the next section – operational ambidexterity – require that the two elements of ambidexterity, exploitation and exploration, are separately measured and then combined. There is significant precedent in the literature for measuring exploitation and exploration by survey questionnaire, but not all of these have been focused in the manufacturing arena, and the detailed methods have not all been designed to allow the exploitation and exploration elements to be numerically combined.

For example, the work carried out by Tamayo-Torres [196] and Kortmann et al [247] (based on Jansen et al [265]) examine exploitation and exploration specifically in the context of *innovation* ambidexterity. In these sources there was limited numerical treatment of the two individual elements.

Brion et al [67] and Wang & Rafiq [246] separately measure exploitation and exploration based on the metrics originally conceived by He & Wong [244] and Atuahene-Gima [99]. Although there is some numerical treatment of the exploitation and exploration elements, the approaches used are inconsistent.

Patel et al [195] focus on *operational ambidexterity* which most closely aligns with the manufacturing focus of this research. Their measures are based on Lubatkin et al [84] which in turn is an extension of He & Wong [244].

Patel et al use their balanced exploitation and exploration measures in combination – taking averages and differences to gauge the balance and absolute level of exploitation and exploration. The question sets below have therefore been selected for use and are taken from Patel, with the exception of the last question under ‘exploration’ because it was missing in Patel’s paper – this is taken from Lubatkin et al [84]. All responses are graduated across a 5-point scale ranging from ‘strongly disagree’ to ‘strongly agree’.

#### **Exploration**

*During the past 3 years indicate the extent to which you agree with the nature of innovation orientation in the operations department of your firm:*

1. *Bases its success on its ability to explore new operational technologies*
2. *Creates products or services that are innovative to the firm*
3. *Looks for creative ways to satisfy its customers’ needs*

4. *Aggressively ventures into new product segments*
5. *Actively seeks new manufacturing technologies and systems*
6. *Actively targets new customer groups.*

## **Exploitation**

*During the past 3 years indicate the extent to which you agree with the nature of innovation orientation in the operations department of your firm:*

1. *Commits to improve quality and lower cost*
2. *Continuously improves the reliability of its products and services*
3. *Increases the levels of automation in its operations*
4. *Constantly surveys existing customers' satisfaction*
5. *Fine-tunes operational activities to keep its current customers satisfied*
6. *Continuously improves existing operational processes*

With these elements in place, exploration can be subtracted from exploitation to reveal the level of exploitation dominance.

### **5.2.3.7 Operational Ambidexterity**

This scale item utilises the same survey scales of exploration and exploitation to derive the operational ambidexterity measure. Patel et al present the methodology for this calculation which is simply the *absolute* difference between exploration and exploitation.

$$\text{Operational Ambidexterity} = | \text{Exploration} - \text{Exploitation} | \quad [195, \text{p}206]$$

### **5.2.3.8 Manufacturing Flexibility**

There are many examples in the literature of manufacturing flexibility being measured by survey questionnaire. These examples include; Ward & Duray [172], Boyer & Lewis [239], Joshi et al [266], Rosenzweig & Roth [203], Peng et al [182, 198], Chung & Swink [204], Camisón & Villar López [135], Kristal et al [194], Liu et al [193], Schroeder

et al [183], Tamayo-Torres et al [196], Patel et al [195], Jin et al [178], Kim et al [267], Gonzalez-Benito & Lannelongue [173], Kortmann et al [247] and Liu et al [268].

Survey instruments in these examples vary substantially in length and the area of focus under investigation. Tamayo-Torres et al [196] and Patel et al [195] employ very detailed and extensive surveys that contain in excess of 20 questions. In contrast, Ward & Duray [172], Boyer & Lewis [239], Joshi et al [266], Chung & Swink [204], Camisón & Villar López [135], Kristal et al [194], Liu et al [193], Schroeder et al [183] and Gonzalez-Benito & Lannelongue [173] all use only 3-5 very similar questions to address manufacturing flexibility.

It is proposed to strike a balance between these extremes of question set length by selecting Jin et al's [178] question set which consists of seven questions and addresses not only manufacturing flexibility for mature products but also for new product introductions. All responses are graduated across a 5-point scale ranging from 'strongly disagree' to 'strongly agree'.

1. Our firm can introduce new products efficiently
2. Our firm can implement many different product modifications
3. Our firm can implement product modifications efficiently
4. Our firm's manufacturing system can operate at many high and low production volumes
5. Our firm's manufacturing system can change production volumes efficiently
6. Our firm's manufacturing system can accommodate many different product mixes
7. Our firm's manufacturing system can change product mixes efficiently

#### **5.2.3.9 Product Portfolio Complexity**

It is important that the selected survey instrument is generally applicable across manufacturing business types and that it can be effectively responded to by a range of senior management that do not necessarily require specialist manufacturing knowledge. This is considered as a variety of approaches to the measurement of product portfolio complexity are discussed below.

Literature sources in this area reveal that complexity in manufacturing businesses resulting from the profile of the product portfolio has been measured using different nomenclature. For example:

- **Product variety** – MacDuffie & Sethuraman [269] and Ramdas [270]
- **Product design & range complexity** – Foster & Gupta [271]
- **Output or goal diversity** – Flynn & Flynn [272]
- **Manufacturing complexity** – Bozarth et al [273]

MacDuffie & Sethuraman [269] measure **product variety** in an automotive-specific context and at three levels:

- Model mix complexity
- Parts complexity
- Option content

Foster & Gupta [271] analysing electronics manufacture, measure **product design and range complexity** using the following dimensions:

- Number of parts on materials record file
- Number of material structure levels in an average product
- Total number of part numbers in an average product
- Number of products on price list
- Average number of options shipped per month
- Number of price listed products with 80% of business
- Number of new products introduced this year

Flynn & Flynn [272] look at the effect that the complexity of the manufacturing environment has on performance. One component of their complexity construct is **output**, or **goal diversity**. The metric for output diversity that Flynn & Flynn propose relates entirely to product complexity:

- Number of active part numbers
- Number of product lines
- Number of final product configurations
- Number of raw materials and purchased parts
- Number of different assemblies
- Number of product families

In a similar vein, Bozarth et al [273] assess **manufacturing complexity** using dimensions that are ostensibly product portfolio related:

- Number of active part numbers
- Number of products manufactured at the plant
- Manufacturing schedule instability
- Degree of low volume batch production

The measures proposed by MacDuffie & Sethuraman, Foster & Gupta, Flynn & Flynn and Bozarth et al described above require survey responses from relatively knowledgeable individuals in the business because of the numeric nature of the questions. Closs et al [274], who focus specifically on product portfolio complexity, suggest a broader approach than simple product count, and this is supported by Solberg [275] who measures product complexity across a small number of reflective item Likert scales.

The approach that has been selected is based on the work by Chapman & Hyland [276] who measure product portfolio complexity using four reflective, five-point Likert-style measures that are summated to give an overall score as follows:

### **1. Product Complexity**

*How complex are the majority of your company's products?*

1. Very few distinct components are needed, and the relations between them are simple and clear
2. Few distinct components are needed
3. A moderate number of distinct components are needed
4. A large number of distinct components are needed
5. A very large number of distinct components are needed. They are both closely interrelated and involve complex linkages.

### **2. Process Complexity**

*How complex is the structure of the production processes for the majority of the company's products?*

1. Very few distinct production steps are needed, and the relations between them are simple and clear.
2. Few distinct production steps are needed
3. A moderate number of production steps are needed
4. A large number of production steps are needed
5. A very large number of production steps are needed. They are both closely interrelated and involve complex linkages.

### **3. Technology complexity**

*How many core technologies are involved in the development and production of the majority of your company's products? ("Core Technologies" as used here may be defined as those product or process technologies that directly affect the company's competitive advantage.)*

1. Only one core technology
2. Two dissimilar core technologies
3. Three dissimilar core technologies
4. Four dissimilar core technologies
5. More than four dissimilar core technologies.

### **4. Customer Interface Complexity**

*How complex is the customer interface for the majority of your company's products?*

1. No variation in customer expectations
2. Minor variation in customer expectations
3. Moderate variation in customer expectations, subtle differences in product characteristics are not too important
4. High specificity of customer expectations, subtle differences in product characteristics are important
5. Very high specificity of customer expectations, subtle differences in product characteristics are of great importance.

Having identified peer-reviewed questions sets for the nine OF-AF Gap construct scale items identified in section 5.2.2 the next section describes the selection of peer-reviewed question sets for the four main model variables.

## **5.3 Main Model Variables**

This section describes the selection of peer-reviewed question sets for the main model variables – Firm Performance, Environmental Turbulence, Emergent Strategy Bias and Innovation Propensity. Consideration must be given to the applicability of questions to a wide range of industry sectors, and the ability of individual respondents to effectively answer questions across a range of topics.

### 5.3.1 Firm Performance

Consideration has been given to using a question set yielding numeric responses, however there is concern over the comparability of responses and the ability of individual respondents to access this type of financial data. Using subjective, reflective measures overcome these issues and Langerak et al confirm the suitability of using subjective performance measures [277, p85].

There are numerous examples of subjective question sets designed to measure firm performance compared to competitors. Examples include Gupta & Lonial [171], Ward & Duray [172], Chung & Swink [204], Camisón & Villar López [135], Kristal et al [194], Lin et al [278] and Akgun & Keskin [279].

Individual questions across these sources are similar and Chung & Swink's [204] specific question set has been selected. The question set comprises five evaluations against competitors, with responses elicited across a 7-point Likert-type scale ranging from 'much worse' to 'much better'.

*Please rate your business' performance relative to your major competitors in terms of:*

*Productivity*

*Profitability*

*Market share of major product or product line*

*Growth rate in unit sales*

*Ability to produce a range of products*

### 5.3.2 Environmental Turbulence

There is a range of nomenclature and approaches found in the literature that seeks to measure environmental turbulence. Ward & Duray [172] and Barrales-Molina et al [144] focus on 'environmental dynamism'. Camisón & Villar López [135] and Calantone & Rubera [60] focus on 'environmental uncertainty'.

A common approach is to separately evaluate the technological turbulence and market turbulence and to subsequently combine these elements. Akgun & Keskin [279], Su et al [154] and Paladino [114] are typical of this approach. Paladino's [114] question set

has been selected for use in this research. The questions are grouped into two sections with responses graduated across a 5-point scale ranging from 'strongly disagree' to 'strongly agree'.

**Market Turbulence Questions:**

1. *In our kind of business, customers' product preferences change over time*
2. *Our customers tend to look for new products all the time.*
3. *Sometimes our customers are price sensitive, but on other occasions price is relatively unimportant*
4. *We are witnessing demand for our products and services from customers who never bought them before.*
5. *New customers tend to have product-related needs that are different from those of our existing customers.*
6. *We cater to similar customers to those we have in the past (reverse scored).*

**Technological Turbulence Questions:**

7. *The technology in our industry is changing rapidly.*
8. *Technological changes provide big opportunities in our industry.*
9. *It is very difficult to forecast where the technology in our industry will be in the next two to three years.*
10. *A large number of new product ideas have been made possible through technological breakthroughs in our industry.*
11. *Technological developments in our industry are relatively minor (reverse scored).*

The responses to the two sets of questions will be combined into a single environmental turbulence scale. This data manipulation is described in section 7.5.

### **5.3.3 Emergent Strategy Bias**

There are limited examples of quantitative measurement of the degree of emergent strategy development within organisations. Liu et al [193] and Teichert & Bouncken [100] take a simplistic and inadequate approach with limited questions designed to capture this subtle organisational characteristic.



Slevin & Covin [280] build on Mintzberg's [97] original theory of emergent strategy development reviewed in section 2.2.5 by creating an 'emergent-to-planned' strategy scale based on five 7-point Likert scale questions ranging between 'strongly disagree' to 'strongly agree'. A 'low' overall score indicates an emergent strategy pattern and higher scores indicate a planned or intended strategy orientation. The questions are as follows:

1. *We typically don't know what the content of our business strategy should be until we engage in some trial and error actions. (reverse scored)*
2. *My business unit's strategy is carefully planned and well understood before any significant competitive actions are taken.*
3. *Formal strategic plans serve as the basis for our competitive actions.*
4. *My business unit's strategy is typically not planned in advance but, rather, emerges over time as the best means for achieving our objectives become clearer. (reverse scored)*
5. *Competitive strategy for my business unit typically results from a formal business planning process ( i.e. the formal plan precedes the action).*

### 5.3.4 Innovation Propensity

Innovation posture and the propensity to innovate was reviewed in section 2.2.4. There is a range of nomenclature and approaches found in the literature that seeks to measure aspects of innovation that are close in their definition to innovation propensity.

Bierly et al [245] and Calantone & Rubera [60] measure strategic and innovation *posture*, which not only incorporates innovativeness but also 'proactivity' and 'risk-taking'. Dobni [62] directly measures innovation propensity and this question set focuses on the innovation *intent* of the business. There are nine questions in Dobni's question set measured against a 7-point Likert scale ranging between 'strongly disagree' and 'strongly agree'.

1. *Innovation is an underlying culture and not just a word.*
2. *Our business model is premised on the basis of strategic intent.*
3. *Our senior managers are able to effectively cascade the innovation message throughout the organisation.*

4. *We have an innovation vision that is aligned with projects, platforms, or initiatives.*
5. *This organisation's management team is diverse in their thinking in that they have different views as to how things should be done.*
6. *There is a coherent set of innovation goals and objectives that have been articulated.*
7. *Innovation is a core value in this organisation.*
8. *We have continuous strategic initiatives aimed at gaining a competitive advantage.*
9. *Our strategic planning process is opportunity oriented as opposed to process oriented.*

### 5.3.5 Question Set Summary

Table 10 summarises the peer-reviewed sources of question sets for each scale variable of the OF-AF Gap construct and the four main model variables described in sections 5.2 and 5.3.

Variable	Question Set Source
Asset Utilisation	Tipper et al [252]
Age of Assets	McKone et al [256]
Continuous Improvement	Peng et al [182]
Training	Tamayo-Torres et al [196]
Operational Absorptive Capacity	Cepeda-Carrion [152]
Exploitation Domination	Patel et al [195]
Operational Ambidexterity	
Manufacturing Flexibility	Jin et al [178]
Product Portfolio Complexity	Chapman & Hyland [276]
Firm Performance	Chung & Swink [204]
Environmental Turbulence	Paladino [114]
Emergent Strategy Bias	Slevin & Covin [280]
Innovation Propensity	Dobni [62]

**Table 10 – OF-AF Gap & Main Model Question Set Sources**

## 5.4 Unidimensionality

In section 4.3.6.1 the benefits of *parcelling* was discussed in connection with the aggregation of individual question responses to create a single numeric 'score' for each scale item. The benefits are significant provided the scale item is unidimensional. The unidimensionality of the peer-reviewed question sets selected and summarised in table 10 is considered here.

The question sets for **Asset Utilisation** (Tipper et al [252]) and **Age of Assets** (McKone et al [256]) consist of single questions and therefore require no parcelling and are unidimensional by definition.

Peng et al confirm the composite reliability, and therefore the unidimensionality, of their **Continuous Improvement** measure with a Cronbach alpha coefficient of 0.79 [182, pp741-2].

Tamayo-Torres et al confirm the unidimensionality of their **Training** measure, and state a reliability coefficient of 0.912 [196, p6184].

Cepeda-Carrion's **Operational Absorptive Capacity** metric is a combination (summation) of potential and realised absorptive capacity. Both of these elements are shown to have reliability coefficients comfortably greater than the recommended 0.7 level [152, p118].

Similarly, **Exploitation Domination** and **Operational Ambidexterity** are combinations of two related elements – exploitation and exploration. Patel et al's measurement of these items are both shown to be unidimensional with Cronbach coefficients greater than 0.8 [195, p215].

Jin et al confirm the unidimensionality of their **Manufacturing Flexibility** measure, and state a reliability coefficient of 0.86 [178, p5719].

The research presented by Chapman & Hyland [276] regarding **Product Portfolio Complexity** does not explicitly report reliability or unidimensionality information and these criteria arising from the main survey of this research will need to be investigated.

Similarly the research presented by Chung & Swink [204] regarding **Firm Performance** does not explicitly report reliability or unidimensionality information and these criteria arising from the main survey of this research will need to be investigated.

Paladino confirms the unidimensionality of her **Environmental Turbulence** measures, and states reliability coefficients greater than 0.7 [114, p587].

Slevin & Covin confirm the unidimensionality of their **Emergent Strategy Bias** measure, and state a reliability coefficient of 0.89 [280, p198].

Dobni confirms the unidimensionality of his **Innovation Propensity** measure, and states a reliability coefficient of 0.71 [62, p352]

The evidence from the literature sources for the question sets to be used in this research is that there was a high degree of reliability and unidimensionality in the data elicited from the survey instruments in their original setting. These results will be revalidated using the responses received from the survey instrument of this research. Therefore the reliability and unidimensionality of all the scale item responses associated with this research will be reported and discussed in chapter 8.

## 5.5 Research Demography

A number of demographic survey questions will be used in order to categorise responses and to provide for the potential to analyse differences between response groups. A review of over twenty research articles using quantitative survey techniques in this research area was used to collate an appropriate initial set of questions. The demographic questions used in the pilot survey are set out below.

### 5.5.1 Industry

Respondents are asked to declare the industry within which their organisation operates.

*Which of the following best describes the principal industry of your organisation?*

- |                                    |   |
|------------------------------------|---|
| <i>Agriculture</i>                 | <i>Government</i>                           |
| <i>Airlines &amp; Aerospace</i>    | <i>Healthcare &amp; Pharmaceuticals</i>     |
| <i>Automotive</i>                  | <i>Retail &amp; Consumer Durables</i>       |
| <i>Construction</i>                | <i>Telecommunications &amp; Electronics</i> |
| <i>Defence</i>                     | <i>Transportation &amp; Delivery</i>        |
| <i>Entertainment &amp; Leisure</i> | <i>Utilities, Energy &amp; Extraction</i>   |
| <i>Food &amp; Beverages</i>        | <i>Other (please specify)</i>               |

### 5.5.2 Age of Business

The maturity of the respondent's business is assessed with the following question.

*How many years has your company been in business?*

- *Less than 5*
- *5 – 10*
- *11 – 15*
- *16 – 20*
- *Over 20*

### 5.5.3 Company Ownership

The structure of the ownership of the business could affect the drive and propensity in the organisation. The following question captures this distinction.

*What is the ownership structure of your business?*

- *Publicly traded*
- *Privately owned*
- *Government*
- *Non-profit*
- *Other (please specify)*

### 5.5.4 Company Size

Two questions are used to gauge the size of the participating individual's business.

*What is the total number of full-time employees?*

- *1 – 10*
- *11 – 50*
- *51 – 250*
- *251 – 1000*
- *1001 – 5000*
- *More than 5000*

*What is your company's annual sales revenue?*

- *Less than £10m*
- *£11m - £50m*
- *£51m - £100m*
- *£101m - £500m*
- *More than £500m*

### 5.5.5 R&D Investment

This question facilitates investigation into the relationship between R&D investment and innovation.

*What proportion of sales revenue do you estimate is invested in R&D and product development?*

- *Less than 0.5%*
- *0.5% to 1%*
- *1% to 2%*
- *2% to 5%*
- *5% to 10%*
- *More than 10%*

### 5.5.6 Manufacturing Facility

The following two questions ascertain the location of the primary manufacturing facility that serves the organisation and establish the dominant manufacturing process type.

*Where is your primary manufacturing facility located?*

- *England – South West*
- *England – South East*
- *England – London*
- *England – East*
- *England – East Midlands*
- *England – West Midlands*
- *England – Yorkshire & the Humber*
- *England – North East*
- *England – North West*
- *Northern Ireland*
- *Republic of Ireland*
- *Scotland*
- *Wales*
- *Other (please specify)*

*What is the dominant manufacturing process type?*

- *Make-to-stock*
- *Make-to-order*
- *Assemble-to-order*
- *Engineer-to-order*

### 5.5.7 Respondent Profile

The survey instrument contains questions across a spectrum of topics that require good general knowledge of the business and the way the organisation develops and realises its strategy. The seniority and discipline of the respondent is likely to affect the quality of the responses. The following two questions establish these characteristics of the respondent.

*What is your position within the company?*

- *Director*
- *Senior Manager*
- *Manager*
- *Operational Level*

*What business discipline most closely matches your role?*

- *General Management*
- *Finance*
- *Manufacturing*
- *Engineering*
- *IT*
- *Human Resources*
- *Other (please specify)*

## 5.6 Survey Construction

Table 11 summarises the sequence of the survey questionnaire and the number of questions for each item. The survey has been divided into sections to help flow, to group similar topics together and to allow progress to be indicated to the respondent. Particularly academic terms such as ‘ambidexterity’, ‘emergent strategy’ and ‘absorptive capacity’ referred to in table 11, were not used in the links between sections of the questionnaire to avoid respondent confusion.

The questionnaire is of significant length with a total number of 100 questions. Part of the rationale for conducting a pilot survey – reported in chapter 6 – is to establish how long the survey would take to complete. Respondents to the pilot survey were therefore asked to indicate this at the end of the survey. The full text of the pilot survey questionnaire is reproduced in Appendix A, along with the email invitation to participate.

Ref	Topic	Number of Questions
<b>About Your Business</b>		
1	<i>Industry</i>	1
2	<i>Age of business</i>	1
3	<i>Ownership</i>	1
4	<i>Sales Revenue</i>	1
5	<i>R&amp;D Investment</i>	1
6	<i>Number of Employees</i>	1
7	<i>Respondent Seniority</i>	1
8	<i>Respondent Discipline</i>	1
<b>Business Environment &amp; Relative Performance</b>		
9	Environmental Turbulence	11
10	Firm Performance	5
<b>Strategic Approach</b>		
11	Innovation Propensity	9
12	Emergent Strategy Bias	5
<b>Manufacturing Facilities &amp; Flexibility</b>		
13	<i>Facility Location</i>	1
14	Age of Assets	5
15	<i>Dominant Process Type</i>	1
16	Asset Utilisation	1
17-20	Product Portfolio Complexity	4
21	Manufacturing Flexibility	7
<b>Innovation &amp; Continuous Improvement</b>		
22	Ambidexterity	12
23	Continuous Improvement	5
<b>Training &amp; Knowledge Management</b>		
24	Training	4
25	Potential Absorptive Capacity	9
26	Realised Absorptive Capacity	12
<b>Survey Feedback</b>		
27	Time to complete survey	1

**Table 11 – Pilot Survey Structure**

Demographic questions are indicated in *italics*.



## 5.7 Chapter Summary

This chapter has implemented the research methodology developed over the course of chapter 4. With respect to the development of the new OF-AF Gap construct in section 5.2, it has been critical to follow the first two stages of the process described in section 4.3.6.1 – item generation and scale development. The domain of the new construct was defined in section 5.2.1 and items carefully selected and justified in section 5.2.2. This resulted in nine scale items chosen for inclusion in the new construct. Peer-reviewed question sets were then identified for each of the nine scale items in section 5.2.3.

Peer-reviewed question sets for the main model variables – Firm Performance, Environmental Turbulence, Emergent Strategy Bias and Innovation Propensity were selected in section 5.3 followed by consideration of the unidimensionality of all the selected questions sets in section 5.4.

The research design process has therefore culminated in a survey instrument combining the item scales that make up the new OF-AF gap measure (section 5.2), the four other main model variables (5.3) and the demographic data questions (5.5). The sequence and format of the complete questionnaire was presented in section 5.6 with the full text reproduced in Appendix A.

The next chapter – chapter 6 – describes the process and results of the piloting of this survey to a selection of individuals in a single organisation. The purpose of the pilot is to check the operation and duration of the questionnaire and, critically, the consistency of response from individuals of different seniority and business function.

## Chapter 6: Pilot Survey

This chapter describes the pilot deployment and analysis of the survey developed in Chapter 5. The purpose of the pilot is discussed in section 6.1 with details of the deployment presented in section 6.2. Responses received are analysed and conclusions drawn in section 6.3. Implications for the structure and content of the main survey questionnaire are discussed in section 6.4, and the ideal respondent profile for the main survey is developed in section 6.5. Finally the chapter is summarised in section 6.6.

### 6.1 Pilot Survey Purpose

The purpose of the pilot survey is threefold:

- To check the length, format and operability of the online survey from the user's perspective.
- To understand the level of consistency of response that is achieved from different seniority levels and across different functional disciplines from within the same company. In theory, given that the same business is being evaluated each time, all responses should be identical.
- To use this analysis to develop a target respondent profile to use in the main survey deployment presented in chapter 7.

In order to achieve these objectives the pilot survey was deployed at the author's employer.

### 6.2 Pilot Survey Deployment

Having gained permission from the company's Chief Executive Officer, an email invitation to complete the survey constructed in *SurveyMonkey* was sent to 27 colleagues representing a spread of seniority and functional disciplines. The covering email and the survey itself can be found in appendix A.

The initial invitations were sent in June 2016 and were followed up by two reminder emails and some verbal encouragement to complete the survey. A total of 22 responses were received from the 27 invitations – a response rate of 81%. Three of the 22 responses were not wholly complete, however the responses received to those questions that were answered in the three incomplete responses were used in the analysis.

Table 12 shows the breakdown of the 27 invitees by seniority and business discipline and table 13 shows the breakdown of the 22 responses.

	Director	Senior Manager	Manager	Total
General Management	2	6		<b>8</b>
Engineering	1		3	<b>4</b>
Manufacturing	1		4	<b>5</b>
Scheduling & Purchasing			2	<b>2</b>
Sales & Marketing	1	2		<b>3</b>
HR	1	2		<b>3</b>
Finance	1			<b>1</b>
IT	1			<b>1</b>
	<b>8</b>	<b>10</b>	<b>9</b>	<b>27</b>

**Table 12 – Pilot Survey Invitees**

	Director	Senior Manager	Manager	Total
General Management	1	6		<b>7</b>
Engineering	1		3	<b>4</b>
Manufacturing	1		3	<b>4</b>
Scheduling & Purchasing			2	<b>2</b>
Sales & Marketing		1		<b>1</b>
HR	1	1		<b>2</b>
Finance	1			<b>1</b>
IT	1			<b>1</b>
	<b>6</b>	<b>8</b>	<b>8</b>	<b>22</b>

**Table 13 – Pilot Survey Respondents**

## 6.3 Pilot Survey Analysis

### 6.3.1 Survey Analysis Method

It was not intended that the pilot survey would be used to try to evaluate any of this research's hypotheses. Rather it was to be used to assess the level of consistency of response from multiple respondents from the same company in order to refine survey questions for clarity of understanding, and to develop an ideal profile of target respondent. Each of the first 26 groups of questions from table 11 were analysed for consistency across disciplines and between seniority levels.

Responses were therefore grouped as follows for analysis. Note that Sales & Marketing, Finance and IT were grouped together to avoid having groups with single respondents.

#### Seniority Groupings:

• Directors	6 responses	} 22 responses
• Senior Managers	8 responses	
• Managers	8 responses	

#### Discipline Groupings:

• General Management	7 responses	} 22 responses
• Engineering	4 responses	
• Manufacturing	4 responses	
• Scheduling & Purchasing	2 responses	
• HR	2 responses	
• Sales & Marketing, Finance and IT	3 responses	

This author found no precedent in reviewed literature for an analysis of response consistency within a single organisation and therefore a dedicated approach for this research was developed. When considering responses to reflective, Likert-scale questions a method to evaluate response consistency was applied to each of the 85 questions of this type.

- Each response was codified using a numeric scale – either 1 to 5, or 1 to 7 depending on the Likert scale range.
- An aggregate response score for a particular question – a simple average – for each of the nine groups above was calculated. This will be termed the **group average**.
- An aggregate response score for a particular question – a simple average – for the entire set of responses was calculated. This will be termed the **survey average**.
- The first metric evaluates whether the minimum response or maximum response in each group is numerically greater than 30% different to the *group average*. The number of times this occurs in a question set is an indication of the consistency *within* groups. This will be termed a **large response range**.
- The second metric evaluates whether the *group average* is greater than 15% different to the *survey average*. This will be termed a **large group divergence**. The number of times this occurs in a question set is an indication of the consistency *between* groups.

The choice of 30% and 15% as the levels at which *response range* and *group divergence* respectively would be deemed to be 'large' was made on the basis of achieving adequate discrimination in the analysis. The objective is to assess respondent consistency so these 'trigger' levels need to be set to ensure this effect can be observed, and conclusions drawn.

If the levels chosen are 'too low' then most questions will be deemed to generate an indication of inconsistency. Set the levels 'too high' and no indications of inconsistency will be generated. The levels selected are particular to this research and allow the effect on the consistency of any changes to respondent groupings to be assessed.

## 6.3.2 Survey Response Analysis

The analysis has been grouped in line with the six survey section headings shown in table 11 and in appendix A. The first section – ‘About Your Business’ – consists entirely of demographic questions.

### 6.3.2.1 About Your Business

Unsurprisingly, these simple demographic questions were answered consistently with only two exceptions:

**Question 1** – establishes the industry of the organisation. Several respondents selected the ‘other’ category and used the free text field to enter ‘manufacturing’ as their response. To guard against this, the phrasing of the question was changed for the main survey from:

*‘Which of the following best describes the principal industry of your organisation?’*

to:

*‘Which of the following best describes the principal industry that your manufacturing business serves?’*

**Question 5** – establishes the level of R&D investment. The range of responses indicated that the respondents’ understanding of the question was inconsistent. The phrasing of the question was changed for the main survey from:

*‘What proportion of sales revenue do you estimate is invested in R&D and product development?’*

to:

*‘What proportion of sales revenue do you estimate is invested in research, new product development and the continuous development of existing products?’*

Additionally, **Question 8** which establishes the respondents’ functional discipline would benefit from additional categories. Therefore ‘Sales & Marketing’ and ‘Scheduling & Purchasing’ were added as options for the main survey.

### 6.3.2.2 Business Environment & Relative Performance

This, and subsequent, sections of the pilot survey were analysed using the approach outlined in section 6.3.1. The number of *large response ranges* and *large group divergences* together indicate the level of consistency of response to the questions. Large response ranges are indicated in the tables below by an 'rr' when the minimum **or** maximum response deviates by more than 30% from the group average, while an 'RR' indicates when both minimum **and** maximum response exhibits this level of deviation. Large group divergences are indicated in the table by a 'GD'.

Responses are presented in tables 14 to 24 and conclusions drawn in section 6.3.3.

Q9 Environmental Turbulence	Seniority			Discipline					
	Directors	Shr Managers	Managers	Gen Manag't	Engineering	Manufacturing	Scheduling Purchasing	HR	Marketing, Finance & IT
When considering the technological environment your business operates within, indicate the extent of your agreement with the following statements:									
<i>a. In our kind of business, customers' product preferences change over time</i>									
Inconsistency Indicators		rr	RR	RR		rr			
<i>b. Our customers tend to look for new products all the time</i>									
Inconsistency Indicators								GD	
<i>c. Sometimes our customers are price sensitive, but on other occasions price is relatively unimportant</i>									
Inconsistency Indicators	RR	RR		RR		RR			
<i>d. We are witnessing demand for our products and services from customers who never bought them before</i>									
Inconsistency Indicators			RR			RR			
<i>e. New customers tend to have product-related needs that are different from those of our existing customers</i>									
Inconsistency Indicators							GD		
<i>f. We cater to similar customers to those we have in the past</i>									
Inconsistency Indicators		rr		rr					
<i>g. The technology in our industry is changing rapidly</i>									
Inconsistency Indicators	rr					GD		rr,GD	
<i>h. Technological changes provide big opportunities in our industry</i>									
Inconsistency Indicators			rr			rr			
<i>i. It is very difficult to forecast where the technology in our industry will be in the next two to three years</i>									
Inconsistency Indicators		RR					GD		rr,GD
<i>j. A large number of new product ideas have been made possible through technological breakthroughs in our industry</i>									
Inconsistency Indicators								GD	
<i>k. Technological developments in our industry are relatively minor</i>									
Inconsistency Indicators								GD	GD

Table 14 – Pilot Survey Q9 Analysis

Q10 Relative Performance	Seniority			Discipline					
	Directors	Snr Managers	Managers	Gen Manag't	Engineering	Manufact'g	Scheduling Purchasing	HR	Marketing, Finance & IT
Please rate your business's performance relative to your major competitors:									
<i>a. Productivity</i>									
Inconsistency Indicators		rr	rr	rr	rr		rr,GD		
<i>b. Profitability</i>									
Inconsistency Indicators			rr			rr			
<i>c. Market share of major product or product line</i>									
Inconsistency Indicators									
<i>d. Growth rate in unit sales</i>									
Inconsistency Indicators	rr		rr				rr,GD	rr	
<i>e. Ability to produce a range of products</i>									
Inconsistency Indicators	rr	RR	rr	RR		GD	rr,GD		rr

Table 15 – Pilot Survey Q10 Analysis

### 6.3.2.3 Strategic Approach

Q11 Innovation Propensity	Seniority			Discipline					
	Directors	Snr Managers	Managers	Gen Manag't	Engineering	Manufact'g	Scheduling Purchasing	HR	Marketing, Finance & IT
Please indicate the extent of your agreement with the following statements concerning the role of innovation in your business:									
<i>a. Innovation is an underlying culture and not just a word</i>									
Inconsistency Indicators	RR	RR	rr	RR	rr,GD		rr,GD	GD	rr
<i>b. Our business model is premised on the basis of strategic intent</i>									
Inconsistency Indicators	rr	rr	rr	rr	rr	rr			GD
<i>c. Our senior managers are able to effectively cascade the innovation message throughout the organisation</i>									
Inconsistency Indicators	rr				rr,GD				
<i>d. We have an innovation vision that is aligned with projects, platforms, or initiatives</i>									
Inconsistency Indicators	rr	rr	rr	rr	rr,GD		GD		
<i>e. The management team is diverse in their thinking in that they have different views as to how things should be done</i>									
Inconsistency Indicators	rr	rr		rr	rr				
<i>f. There is a coherent set of innovation goals and objectives that have been articulated</i>									
Inconsistency Indicators	rr	RR	RR	RR	rr	RR		rr,GD	
<i>g. Innovation is a core value in this organisation</i>									
Inconsistency Indicators	rr,GD	RR	rr	RR	rr,GD	RR		GD	rr,GD
<i>h. We have continuous strategic initiatives aimed at gaining a competitive advantage</i>									
Inconsistency Indicators	RR	RR	rr	RR	rr	rr		rr	rr,GD
<i>i. Our strategic planning process is opportunity oriented as opposed to process oriented</i>									
Inconsistency Indicators	RR	rr	rr	rr	rr	rr			rr,GD

Table 16 – Pilot Survey Q11 Analysis



Q12 Emergent Strategy Bias	Seniority			Discipline					
	Directors	Snr Managers	Managers	Gen Manag't	Engineering	Manufact'g	Scheduling Purchasing	HR	Marketing, Finance & IT
Please indicate the extent of your agreement with the following statements concerning how strategy is developed in your business:									
<i>a. We typically don't know what the content of our business strategy should be until we engage in some trial &amp; error actions</i>									
Inconsistency Indicators	rr	rr	rr	rr	rr,GD	rr			GD
<i>b. My business unit's strategy is carefully planned and well understood before any significant competitive actions are taken</i>									
Inconsistency Indicators			rr			rr			GD
<i>c. Formal strategic plans serve as the basis for our competitive actions</i>									
Inconsistency Indicators	rr		rr		rr	rr			GD
<i>d. My business unit's strategy is typically not planned in advance but, rather, emerges over time as the best means for achieving our objectives become clearer</i>									
Inconsistency Indicators	rr		rr			rr			rr
<i>e. Competitive strategy for my business unit typically results from a formal business planning process (i.e. the formal plan precedes the action)</i>									
Inconsistency Indicators	rr		rr		rr	rr			GD

Table 17 – Pilot Survey Q12 Analysis

#### 6.3.2.4 Manufacturing Facilities & Flexibility

**Questions 13** and **15** in this section relating to the location of the manufacturing facility and the manufacturing process type were answered consistently. **Question 14** which establishes the age of the equipment in the manufacturing facility, and **Question 16** which assesses the ability to increase output without increasing cost are reviewed in table 18.

Q14 Age of Assets Q16 Asset Utilisation	Seniority			Discipline					
	Directors	Snr Managers	Managers	Gen Manag't	Engineering	Manufact'g	Scheduling Purchasing	HR	Marketing, Finance & IT
<i>Respondents asked to estimate the proportion of equipment that fell into five age categories. Equipment age is calculated as a weighted average of responses.</i>									
Inconsistency Indicators	RR	RR	RR	RR				RR,GD	
<i>Ability to increase output without increasing cost.</i>									
Inconsistency Indicators	rr	rr	rr	rr		rr			rr

Table 18 – Pilot Survey Q14 & Q16 Analysis

Q17 – Q20 Product Portfolio Complexity	Seniority			Discipline					
	Directors	Snr Managers	Managers	Gen Manag't	Engineering	Manufact'g	Scheduling Purchasing	HR	Marketing, Finance & IT
<i>Q17. How complex are the majority of your company's products?</i>									
Inconsistency Indicators		rr						GD	rr,GD
<i>Q18. How complex is the structure of the production processes for the majority of the company's products?</i>									
Inconsistency Indicators	rr,GD	rr							RR
<i>Q19. How many core technologies are involved in the development and production of the majority of your company's products?</i>									
Inconsistency Indicators	rr	rr	rr	rr	GD	GD	rr	rr,GD	rr,GD
<i>Q20. How complex is the customer interface for the majority of your company's products?</i>									
Inconsistency Indicators									GD

**Table 19 – Pilot Survey Q17 – Q20 Analysis**

Q21 Manufacturing Flexibility	Seniority			Discipline					
	Directors	Snr Managers	Managers	Gen Manag't	Engineering	Manufact'g	Scheduling Purchasing	HR	Marketing, Finance & IT
When considering the flexibility of your manufacturing facility, please indicate the extent of your agreement with the following statements:									
<i>a. Our firm can introduce new products efficiently</i>									
Inconsistency Indicators		rr						rr,GD	rr
<i>b. Our firm can implement many different product modifications</i>									
Inconsistency Indicators		rr	rr	rr		rr			
<i>c. Our firm can implement product modifications efficiently</i>									
Inconsistency Indicators	rr	rr				GD		RR,GD	rr
<i>d. Our firm's manufacturing system can operate at many high and low production volumes</i>									
Inconsistency Indicators	rr	rr	rr	rr		rr		rr,GD	rr
<i>e. Our firm's manufacturing system can change production volumes efficiently</i>									
Inconsistency Indicators		rr							rr,GD
<i>f. Our firm's manufacturing system can accommodate many different product mixes</i>									
Inconsistency Indicators		rr		rr,GD			GD		
<i>g. Our firm's manufacturing system can change product mixes efficiently</i>									
Inconsistency Indicators		rr							rr

**Table 20 – Pilot Survey Q21 Analysis**

### 6.3.2.5 Innovation & Continuous Improvement

Q22 Ambidexterity	Seniority			Discipline					
	Directors	Snr Managers	Managers	Gen Manag't	Engineering	Manufacturing	Scheduling Purchasing	HR	Marketing, Finance & IT
Please indicate the extent to which you agree with the following statements relating to the nature of the innovation orientation of your operations during the past 3 years:									
<i>a. Bases its success on its ability to explore new operational technologies</i>									
Inconsistency Indicators		rr	rr	rr	rr,GD	rr	GD	GD	GD
<i>b. Creates products or services that are innovative to the firm</i>									
Inconsistency Indicators					GD				
<i>c. Looks for creative ways to satisfy its customers' needs</i>									
Inconsistency Indicators		rr		rr					
<i>d. Aggressively ventures into new product segments</i>									
Inconsistency Indicators			rr			rr			
<i>e. Actively seeks new manufacturing technologies and systems</i>									
Inconsistency Indicators							GD		GD
<i>f. Actively targets new customer groups</i>									
Inconsistency Indicators		rr		rr					
<i>g. Commits to improve quality and lower cost</i>									
Inconsistency Indicators		rr	rr	rr	rr,GD		rr	GD	GD
<i>h. Continuously improves the reliability of its products and services</i>									
Inconsistency Indicators		rr		rr				GD	GD
<i>i. Increases the levels of automation in its operations</i>									
Inconsistency Indicators	rr	rr						rr,GD	rr
<i>j. Constantly surveys existing customers' satisfaction</i>									
Inconsistency Indicators		rr						rr,GD	
<i>k. Fine-tunes operational activities to keep its current customers satisfied</i>									
Inconsistency Indicators							GD		GD
<i>l. Continuously improves existing operational processes</i>									
Inconsistency Indicators									

Table 21 – Pilot Survey Q22 Analysis

Q23 Continuous Improvement	Seniority			Discipline					
	Directors	Snr Managers	Managers	Gen Manag't	Engineering	Manufact'g	Scheduling Purchasing	HR	Marketing, Finance & IT
Please indicate the extent of your agreement with the following statements relating to continuous improvement in your business:									
<i>a. We strive to continually improve all aspects of products and processes, rather than taking a static approach</i>									
Inconsistency Indicators									
<i>b. We search for continued learning and improvement, after the installation of new equipment</i>									
Inconsistency Indicators		rr		rr					GD
<i>c. Continuous improvement makes our performance a moving target, which is difficult for competitors to attack</i>									
Inconsistency Indicators					GD				
<i>d. We believe that improvement of a process is never complete; there is always room for more incremental improvement</i>									
Inconsistency Indicators								GD	GD
<i>e. Our organisation is not a static entity, but engages in dynamically changing itself to better serve its customers</i>									
Inconsistency Indicators									

Table 22 – Pilot Survey Q23 Analysis

### 6.3.2.6 Training & Knowledge Management

Table 23 analyses responses to **Question 24** relating to organisational learning – the reflective item scale corresponding to the ‘training’ component of the OF-AF Gap.

Q24 Organisational Learning	Seniority			Discipline					
	Directors	Snr Managers	Managers	Gen Manag't	Engineering	Manufact'g	Scheduling Purchasing	HR	Marketing, Finance & IT
When considering organisational learning, please indicate the extent of your agreement with the following statements:									
<i>a. The organisation has learned or acquired much new and relevant knowledge over the last three years</i>									
Inconsistency Indicators		rr					GD	rr	
<i>b. Organisational members have acquired critical capacities and skills over the last three years</i>									
Inconsistency Indicators									
<i>c. The organisation's performance has been influenced by new learning it has acquired over the last three years</i>									
Inconsistency Indicators	rr	RR		RR				RR	
<i>d. The organisation is a learning organisation</i>									
Inconsistency Indicators	rr	rr		rr		rr,GD			

Table 23 – Pilot Survey Q24 Analysis

Q25 & Q26 Knowledge Management	Seniority			Discipline					
	Directors	Snr Managers	Managers	Gen Manag't	Engineering	Manufac'tg	Scheduling Purchasing	HR	Marketing, Finance & IT
Please indicate the extent of your agreement with the following statements that concern knowledge management:									
<i>Q26a. Our unit has frequent interactions with corporate headquarters to acquire new knowledge</i>									
Inconsistency Indicators		RR	rr	RR			rr,GD		
<i>b. Employees of our unit regularly visit other branches</i>									
Inconsistency Indicators		rr		rr				GD	
<i>c. We collect industry information through informal means</i>									
Inconsistency Indicators	rr				rr				
<i>d. Other divisions of our company are rarely visited</i>									
Inconsistency Indicators		RR		RR					rr
<i>e. Our unit periodically organises special meetings with customers or third parties to acquire new knowledge</i>									
Inconsistency Indicators		RR	rr	RR	rr		rr	rr	
<i>f. Employees regularly approach third parties such as accountants, consultants or tax consultants</i>									
Inconsistency Indicators		rr	rr	rr			rr,GD		
<i>g. We are slow to recognise shifts in our market (e.g. competition, regulation)</i>									
Inconsistency Indicators			rr			rr			
<i>h. New opportunities to serve our clients are quickly understood</i>									
Inconsistency Indicators	rr	rr	rr	rr	rr	rr,GD	GD		
<i>i. We quickly analyse and interpret changing market demands</i>									
Inconsistency Indicators	rr		rr			rr		rr	
<i>Q27a. Our unit regularly considers the consequences of changing market demands in terms of new products &amp; services</i>									
Inconsistency Indicators	rr							rr,GD	
<i>b. Employees record and store newly acquired knowledge for future reference</i>									
Inconsistency Indicators	rr	RR		RR				rr,GD	rr,GD
<i>c. Our unit quickly recognizes the usefulness of new external knowledge to existing knowledge</i>									
Inconsistency Indicators		rr	rr	rr		rr	rr		GD
<i>d. Employees rarely share practical experiences</i>									
Inconsistency Indicators	rr		rr				rr,GD		rr
<i>e. We work hard to seize the opportunities for our unit from new external knowledge</i>									
Inconsistency Indicators			rr				rr		
<i>f. Our unit periodically meets to discuss consequences of market trends and new product development</i>									
Inconsistency Indicators		rr	rr	rr		rr,GD	rr,GD		rr
<i>g. It is well known how activities within our unit should be performed</i>									
Inconsistency Indicators		rr	rr			rr	GD		rr,GD
<i>h. Client complaints fall on deaf ears in our unit</i>									
Inconsistency Indicators			rr,GD		rr,GD			GD	
<i>i. Our unit has a clear division of roles and responsibilities</i>									
Inconsistency Indicators		rr	rr	rr	rr	rr	rr,GD		
<i>j. We constantly consider how to better exploit knowledge</i>									
Inconsistency Indicators			rr			rr	rr,GD		
<i>k. Our unit has difficulty implementing new products and services</i>									
Inconsistency Indicators	rr	rr	RR		rr	rr,GD	rr,GD	rr,GD	rr
<i>l. Employees have a common language regarding our products and services</i>									
Inconsistency Indicators	GD		rr		rr		GD	GD	

Table 24 – Pilot Survey Q25 & Q26 Analysis

### 6.3.3 Drivers of Inconsistency

Having reviewed pilot survey responses in section 6.3.2 and considered the inconsistency indicators in tables 14 to 24 it is clear that there is a level of inconsistency that requires investigation. This section seeks to address this by considering four potential drivers of inconsistency:

- the effect of respondent groupings by seniority and discipline (section 6.3.3.1)
- the particular structure of the surveyed organisation (section 6.3.3.2)
- the length of tenure of respondents (section 6.3.3.3)
- the lack of clarity of question wording (section 6.3.3.4)

#### 6.3.3.1 Respondent Groupings

Table 25 presents the frequency of *large group divergences* (as defined in section 6.3.1 and indicated by 'GD' in tables 14 to 24) for each of the respondent seniority and discipline groups. Each occurrence represents an instance when the average response score for the group in question is different to the average response from all the participants by greater than 15%. The percentage of each group's question responses that exhibited this divergence is also indicated based on the total of 85 questions that were evaluated in this way.

Group	Participants	GD Freq.	GD %
Directors	6	3	3.5%
Senior Managers	8	0	
Managers	8	1	1.2%
General Management	7	1	1.2%
Engineering	4	11	12.9%
Manufacturing	4	8	9.4%
Scheduling & Purchasing	2	22	25.9%
Human Resources	2	25	29.4%
Sales & Marketing, Finance & IT	3	24	28.2%

Table 25 – Pilot Survey Large Group Divergences

There are very few occurrences (only 4) of large group divergences when looking at the seniority of respondent. However there is significant discrepancy when considering the last three categories of business functions listed in table 25. It is reasonable to conclude that those functions most remote from the central topics of this research will respond with greater divergence when compared to those functions most critically involved in innovation and the development of competitive and manufacturing strategies.

If the ‘ancillary’ disciplines of Scheduling, Purchasing, Human Resources, Sales & Marketing, Finance and IT are excluded from the analysis the total respondents reduce from 22 to 15. The quantity of respondents in the seniority groupings will correspondingly reduce and the whole group average score will also be affected. Consequently the evaluation of large group divergences for the remaining groups will change. This is summarised in table 26.

Group	Participants	GD Freq.	GD %
Directors	3	9	10.6%
Senior Managers	6	0	
Managers	6	1	1.2%
General Management	7	0	
Engineering	4	4	4.7%
Manufacturing	4	3	3.5%

**Table 26 – Group Divergence Analysis Excluding Ancillary Functions**

This represents a substantial improvement (i.e. reduction) in overall instances of group divergence. The instances of group divergence for the Directors group has increased and this could be related to the reduced number of participants in this group. With only three participants in the group the divergence results are more sensitive. The improvement in instances of group divergence is supplemented by a similarly significant reduction in large *range responses* for the seniority groupings. This is summarised in table 27.

Group	Including Ancillary Functions			Excluding Ancillary Functions		
	Participants	‘rr’	‘RR’	Participants	‘rr’	‘RR’
Directors	6	27	5	3	13	2
Senior Managers	8	35	13	6	23	9
Managers	8	37	5	6	26	4

**Table 27 – Range Response Analysis Excluding Ancillary Functions**

Based on these improvements in group divergences and large range responses, *main survey* responses will not be sought from individuals with functional disciplines that include Scheduling, Purchasing, Human Resources, Sales & Marketing, Finance or IT.

### 6.3.3.2 Surveyed Company Structure

Even though excluding the responses of ancillary functions improves the frequency of group divergences to acceptable levels and reduces the instances of large range responses, there remains a significant number of large range responses which suggests a further underlying issue with the data received from the pilot survey.

The surveyed organisation is a little unusual in the sense that it is a combination of two quite different, commercially autonomous businesses – a Sales Division and a Hire Division. There is a distinctly different culture in these two businesses and they put different demands on the manufacturing unit that serves both. The Sales Division is a project-oriented, build-to-order business where innovation in product solutions and speed of response is valued highly. In contrast, the Hire Division focuses on maintaining a hire fleet by building to stock in batches. Here product robustness, compatibility and flexibility is more highly valued than product innovation.

The pilot survey respondents come from across both these businesses and from the central services that support them, so these business differences will inevitably be reflected in their responses. Each response is valid from the individual’s perspective, but in terms of assessing consistency of response from the same organisation an analysis is required with respondents grouped by the individuals’ location in the business – either Sales, Hire or Central Services.

All the respondents from Engineering and Manufacturing disciplines are located in the central services team of the surveyed company. The general management function is split across the Sales and Hire divisions. The demographics of the analysis that follows is shown in table 28.

	Director	Snr Manager	Manager	Total
Hire	1	2		3
Sales		4		4
Central	2		6	8
	3	6	6	15

**Table 28 – Pilot Survey Sales/Hire Respondent Grouping**



The evaluation shown in tables 29 to 39 compares the number of large range responses and large group diversions when the 15 respondents are grouped by functional disciplines of General Management, Engineering and Manufacturing (i.e. the original analysis presented in tables 14 to 24) with the number of inconsistency indicators revealed when the same respondents are grouped by Sales, Hire and Central Services.

If the observation that the two distinct business models will legitimately produce different response profiles is correct, it can be expected that the revised respondent groupings will result in two effects. Firstly, there should be a *reduced* occurrence of large range responses – this is indicated for each question in the right hand column of the tables that follow. Secondly, we should see a *greater* occurrence of large group diversity for the Hire & Sales groups as their distinct nature is revealed.

Q9 Environmental Turbulence	Qty Inconsistency Indicators Original Analysis (Table 14)			Qty Inconsistency Indicators Sales/Hire Grouping			Improved Range Response Consistency
	Gen Mngt	Eng	Manuf	Hire	Sales	Central	
Q9a	RR		rr		rr		Yes
Q9b							
Q9c	RR		RR	rr	rr, GD		Yes
Q9d			RR			rr	Yes
Q9e							
Q9f	rr				rr		
Q9g			GD				Yes
Q9h			rr			rr	
Q9i							
Q9j							
Q9k							

Table 29 – Pilot Survey Q9 Analysis – Sales/Hire Grouping

Q10 Relative Performance	Qty Inconsistency Indicators Original Analysis (Table 15)			Qty Inconsistency Indicators Sales/Hire Grouping			Improved Range Response Consistency
	Gen Mngt	Eng	Manuf	Hire	Sales	Central	
Q10a	rr	rr		rr		rr	
Q10b			rr			rr	
Q10c							
Q10d							
Q10e	RR		GD	rr, GD	rr		

Table 30 – Pilot Survey Q10 Analysis – Sales/Hire Grouping

Q11 Innovation Propensity	Qty Inconsistency Indicators Original Analysis (Table 16)			Qty Inconsistency Indicators Sales/Hire Grouping			Improved Range Response Consistency
	Gen Mngt	Eng	Manuf	Hire	Sales	Central	
Q11a	RR	rr, GD		rr	rr, GD		Yes
Q11b	rr	rr	rr	rr			Yes
Q11c		rr, GD		rr	rr	RR	No
Q11d	rr	rr, GD				rr	Yes
Q11e	rr	rr			rr	rr	
Q11f	RR	rr	RR	rr		rr	Yes
Q11g	RR	rr, GD	RR	rr	rr, GD	RR	Yes
Q11h	RR	rr	rr		rr		Yes
Q11i	rr	rr	rr	rr		rr	Yes

Table 31 – Pilot Survey Q11 Analysis – Sales/Hire Grouping

Q12 Emergent Strategy Bias	Qty Inconsistency Indicators Original Analysis (Table 17)			Qty Inconsistency Indicators Sales/Hire Grouping			Improved Range Response Consistency
	Gen Mngt	Eng	Manuf	Hire	Sales	Central	
Q12a	rr	rr, GD	rr	rr	rr, GD		Yes
Q12b			rr		rr	rr	No
Q12c		rr	rr			rr	Yes
Q12d			rr			rr	
Q12e		rr	rr			rr	Yes

Table 32 – Pilot Survey Q12 Analysis – Sales/Hire Grouping

Q14 & Q16	Qty Inconsistency Indicators Original Analysis (Table 18)			Qty Inconsistency Indicators Sales/Hire Grouping			Improved Range Response Consistency
	Gen Mngt	Eng	Manuf	Hire	Sales	Central	
Q14 Age of Assets	RR				rr		Yes
Q16 Asset Utilisation	rr		rr		rr	rr	

Table 33 – Pilot Survey Q14 & Q16 Analysis – Sales/Hire Grouping

Q17 – Q20 Product Portfolio Complexity	Qty Inconsistency Indicators Original Analysis (Table 19)			Qty Inconsistency Indicators Sales/Hire Grouping			Improved Range Response Consistency
	Gen Mngt	Eng	Manuf	Hire	Sales	Central	
Q17							
Q18							
Q19	rr	GD	GD	rr, GD			Yes
Q20							

Table 34 – Pilot Survey Q17 – Q20 Analysis – Sales/Hire Grouping

Q21 Manufacturing Flexibility	Qty Inconsistency Indicators Original Analysis (Table 20)			Qty Inconsistency Indicators Sales/Hire Grouping			Improved Range Response Consistency
	Gen Mngt	Eng	Manuf	Hire	Sales	Central	
Q21a							
Q21b	rr		rr	GD	rr	rr	
Q21c			GD				Yes
Q21d	rr		rr	GD	rr	rr	
Q21e							
Q21f	rr, GD			GD			Yes
Q21g							

Table 35 – Pilot Survey Q21 Analysis – Sales/Hire Grouping

Q22 Ambidexterity	Qty Inconsistency Indicators Original Analysis (Table 21)			Qty Inconsistency Indicators Sales/Hire Grouping			Improved Range Response Consistency
	Gen Mngt	Eng	Manuf	Hire	Sales	Central	
Q22a	rr	rr, GD	rr	rr			Yes
Q22b		GD					Yes
Q22c	rr			rr, GD	rr		No
Q22d			rr			rr	
Q22e							
Q22f	rr			rr, GD			
Q22g	rr	rr, GD				rr	Yes
Q22h	rr			rr			
Q22i							
Q22j							
Q22k							
Q22l							

Table 36 – Pilot Survey Q22 Analysis – Sales/Hire Grouping

Q23 Continuous Improvement	Qty Inconsistency Indicators Original Analysis (Table 22)			Qty Inconsistency Indicators Sales/Hire Grouping			Improved Range Response Consistency
	Gen Mngt	Eng	Manuf	Hire	Sales	Central	
Q23a				GD			
Q23b	rr			rr			Yes
Q23c		GD					Yes
Q23d							
Q23e							

Table 37 – Pilot Survey Q23 Analysis – Sales/Hire Grouping

Q24 Organisational Learning	Qty Inconsistency Indicators Original Analysis (Table 23)			Qty Inconsistency Indicators Sales/Hire Grouping			Improved Range Response Consistency
	Gen Mngt	Eng	Manuf	Hire	Sales	Central	
Q24a				GD			
Q24b				GD			
Q24c	RR			GD	rr		Yes
Q24d	rr		rr, GD	GD	rr		Yes

Table 38 – Pilot Survey Q24 Analysis – Sales/Hire Grouping

Q25 & Q26 Knowledge Management	Qty Inconsistency Indicators Original Analysis (Table 24)			Qty Inconsistency Indicators Sales/Hire Grouping			Improved Range Response Consistency
	Gen Mngt	Eng	Manuf	Hire	Sales	Central	
Q25a	RR			rr			Yes
Q25b	rr			RR	rr		No
Q25c		rr				rr	
Q25d	RR			rr, GD	rr, GD		No
Q25e	RR	rr		rr, GD	rr		Yes
Q25f	rr						Yes
Q25g			rr			rr	
Q25h	rr	rr	rr, GD	GD		rr	Yes
Q25i			rr			rr	
Q26a							
Q26b	RR			rr			Yes
Q26c	rr		rr		rr	rr	
Q26d							
Q26e							
Q26f	rr		rr, GD	GD		rr	Yes
Q26g			rr			rr	
Q26h		rr, GD		GD		rr	
Q26i	rr	rr	rr	GD	rr	rr	Yes
Q26j			rr			rr	
Q26k		rr	rr, GD			RR	
Q26l		rr				rr	

**Table 39 – Pilot Survey Q25 & Q26 Analysis – Sales/Hire Grouping**

It can be seen from tables 29 to 39 that the revised respondent groupings improve (reduce) the frequency of large range responses (32 of the 85 questions exhibit this improvement). This implies a greater degree of consistency of response for individuals grouped in this way.

Instances of large group divergences with the revised groupings are exclusively found in the Hire and Sales groups. This will inevitably be more likely due to the smaller number of respondents in these groups when compared to the central services group, however the group divergence is particularly evident in the question sets concerning manufacturing flexibility (table 35), organisational learning (table 38) and knowledge management (table 39).

These observations support the proposition above that the nature of the surveyed organisation’s structure has contributed to the appearance of inconsistency – alongside the contribution of ancillary business functions – in the initial review of responses in section 6.3.2 (i.e. tables 14 to 24). When these two effects are accounted for, responses are revealed to be more consistent.

### 6.3.3.3 Respondent Tenure

Analysis of responses from individuals that are relatively new to the business reveal a much more critical standpoint than those whose length of service is much longer. It could be argued that new employees take a more objective view of the business, while long-standing employees are unduly influenced by the prevailing culture and have 'gone native'. To allow interrogation, and the potential to correct for this in the main survey an additional demographic question regarding the respondent's length of tenure is included.

### 6.3.3.4 Clarity of Question Wording

In addition to the need to revise question wording identified in section 6.3.2.1 concerning two particular demographic questions, there was anecdotal feedback from respondents indicating that individuals often responded from the viewpoint of their particular department rather than the business as a whole. To combat this some question wording requires adjustment for the main survey. For example, where the phrase 'your unit' is used in a question, this could be interpreted as referring to a functional department rather than the whole business unit. Details of revised question wording are described in section 6.4.

## 6.3.4 Pilot Survey Analysis Summary

The initial analysis of 22 survey responses from the same organisation revealed a level of inconsistency that required investigation. Four potential drivers of this inconsistency were subsequently considered.

There was reasonable consistency between respondent groups based on seniority, however there was significant discrepancy observed when responses were analysed by discipline. As a result the 'ancillary' disciplines of Scheduling, Purchasing, Human Resources, Sales & Marketing, Finance and IT are excluded from the main survey.

The particular organisational structure of the surveyed organisation, and the distribution of respondents within it has been shown to have contributed to the apparent inconsistency of the original analysis in section 6.3.2. Once this has been corrected for a significantly more consistent response pattern is evident.

Anecdotally, the length of tenure of respondents and the wording of certain questions has also led to a degree of inconsistency in responses. Adjustments to the main survey to address these issues are described in section 6.4.

Having considered and corrected for the four drivers of inconsistency discussed above, the pilot survey can be seen to achieve a much greater level of consistency for multiple respondents from the same organisation.

## 6.4 Modifications for Main Survey

Conclusions drawn from the analysis of the pilot survey responses in section 6.3 have led to a number of changes to the question set to be deployed for the main survey. Care has been taken in making these changes not to undermine the principle of using previously developed survey instruments that have themselves been appropriately tested and peer-reviewed. It is interesting to note, however, that in none of the original sources for these individual question sets has a pilot survey been conducted to establish consistency of response.

The changes to individual questions and the structure of the *main* survey are described below and summarised in table 40. This can be directly compared to the structure of *pilot* survey in table 11.

The most significant changes were made in the first section, the section capturing demographic information about the respondent. The pilot survey revealed the importance of understanding the organisational structure of the business, and ensuring respondents answered questions from a consistent perspective. The first section therefore addresses the structure of the respondent's business and how the manufacturing unit in question relates to it.

Pilot survey question 3 relating to ownership structure becomes the first question in the main survey and is followed by three new questions:

Q2. *Which of the following organisation structures most closely fits your own?*

- *Your business has its own manufacturing facility and is not a subsidiary of a larger group of companies*
- *Your business has its own manufacturing facility and is a subsidiary of a larger group of companies*
- *Your business is a subsidiary of a larger group of companies and shares its manufacturing facility with some or all of those companies*

If the second or third option is selected then questions 2A and 2B are posed. If the first response is selected then these two questions are skipped.

Q2A. *Where is your ultimate parent company's head office located?*

- *UK*
- *EU*
- *US*
- *Other (please specify)*

Q2B. *What is the total number of full-time employees in your group of companies?*

- *1 – 250*
- *251 – 1000*
- *1001 – 5000*
- *More than 5000*

The respondent is then directed to *'answer the rest of the questions in the survey from the perspective of the business you directly work for and the manufacturing facility that it uses'*. The pilot survey questions concerning the number of employees in the local company and its sales revenue is followed by reworded questions regarding R&D investment and industry categorisation as outlined in section 6.3.2.1.

The question establishing R&D investment (Q5) is changed from:

*'What proportion of sales revenue do you estimate is invested in R&D and product development?'*

to:

*'What proportion of sales revenue do you estimate is invested in research, new product development and the continuous development of existing products?'*

The question categorising the respondent's industry (Q6) is changed from:

*'Which of the following best describes the principal industry of your organisation?'*

to:

*'Which of the following best describes the principal industry that your manufacturing business serves?'*

Pilot survey questions relating to the age of the business and the respondent's seniority are unchanged. Additional categories are added to the question concerning the respondent's discipline (Q8) as described in section 6.3.2.1.

Two additional questions have been added at the end of this demographic section of the survey. Question 10 establishes the length of tenure of the respondent in line with observations made in section 6.3.3.3.

*Q10. How long have you worked for this company?*

- *Less than 1 year*
- *1 – 3 years*
- *4 – 7 years*
- *8 – 15 years*
- *More than 15 years*

Question 11 asks the respondent to provide the name of the company they work for. This response is clearly indicated as optional in the survey and is included only to try to identify multiple respondents from the same company. The likelihood of this occurring is influenced by the nature of the distribution of the invitation to take part in the main survey which is described in chapter 7.

The final set of changes are associated with the observation in section 6.3.3.4 that some question terminology could lead to inconsistent interpretation. This is particularly evident in the two questions regarding knowledge management – questions 25 and 26 in the pilot survey, questions 28 and 29 in the main survey.

Throughout these two questions the word ‘business’ has been added in front of each occurrence of the word ‘unit’ in order to try to improve consistency of interpretation. Additionally, three of the questions within question 28 have been modified as follows:

**Q28b.**

From: *Employees of our unit regularly visit other branches*

To: *Employees of our **business** unit regularly visit other **company sites***

**Q28d.**

From: *Other divisions of our company are rarely visited*

To: *Other divisions of our company are rarely visited **by employees of our business unit***

**Q28f.**

From: *Employees regularly approach third parties such as accountants, consultants or tax consultants*

To: *Employees regularly approach third parties such as consultants, **industry experts or academic institutions.***

Table 40 summarises the revised structure of the main survey and the full text of the main survey can be found in Appendix B



Ref	Topic	Number of Questions
<b>About Your Business &amp; Your Role</b>		
1	<i>Ownership Structure</i>	1
2	<i>Organisation Structure</i>	1
2A	<i>Parent Office Location</i>	1
2B	<i>Number of Employees in Group</i>	1
3	<i>Number of Employees in Company</i>	1
4	<i>Sales Revenue</i>	1
5	<i>R&amp;D Investment</i>	1
6	<i>Industry</i>	1
7	<i>Age of business</i>	1
8	<i>Respondent Seniority</i>	1
9	<i>Respondent Discipline</i>	1
10	<i>Respondent Tenure</i>	1
11	<i>Respondent Company (optional)</i>	1
<b>Business Environment &amp; Relative Performance</b>		
12	Environmental Turbulence	11
13	Firm Performance	5
<b>Strategic Approach</b>		
14	Innovation Propensity	9
15	Emergent Strategy Bias	5
<b>Manufacturing Facilities &amp; Flexibility</b>		
16	<i>Facility Location</i>	1
17	Age of Assets	5
18	<i>Dominant Process Type</i>	1
19	Asset Utilisation	1
20-23	Product Portfolio Complexity	4
24	Manufacturing Flexibility	7
<b>Innovation &amp; Continuous Improvement</b>		
25	Ambidexterity	12
26	Continuous Improvement	5
<b>Training &amp; Knowledge Management</b>		
27	Training	4
28	Potential Absorptive Capacity	9
29	Realised Absorptive Capacity	12

**Table 40 – Main Survey Structure**

## 6.5 Main Survey Target Respondent Profile

This research is focused on manufacturing businesses and the characteristics of their production facilities, strategy development, innovation approach and knowledge management. Target respondents for the main survey should therefore occupy positions in manufacturing businesses that provide an objective view of such topics.

The analysis of the responses to the pilot survey to individuals in a single organisation has shown consistency of response across different seniority levels, while respondents from ancillary functions should be avoided (section 6.3.3.1).

Target respondents for the main survey should therefore be:

- Directors, senior managers or managers
- From general management, engineering or manufacturing disciplines

Chapter 7 describes how respondents fitting this profile were targeted. Demographic questions relating to this profile were retained in the survey question set to confirm that the targeting was successful.

## 6.6 Chapter Summary

This chapter has described the deployment of a pilot survey to a single organisation in order to establish an ideal target respondent profile by assessing the degree of consistency between responses.

Analysis of the 22 responses revealed reasonable consistency across seniority levels, while, perhaps unsurprisingly, respondents should be sourced from disciplines most likely to have knowledge in the focus areas of the survey – general management, engineering and manufacturing.

The pilot survey also revealed the effect the structure of the organisation can have on the distribution of responses, and additional demographic questions were added to the main survey question set as a result. Anecdotal feedback from respondents regarding the interpretation of certain questions also led to small changes to their phrasing.

The analysis of the pilot survey results and the consequent changes made for the main survey question set should be seen in the context that, with the exception of the

demographic section, all questions have been derived from peer-reviewed literature which have been appropriately validated in their own right. The pilot survey assessment goes beyond all the question set source literatures by evaluating consistency of response from multiple respondents from the same company.

The resulting survey questionnaire to be used for the main survey can be found in appendix B. The deployment of the main survey is described in the next chapter, chapter 7.

# Chapter 7: Main Survey Deployment

## 7.1 Introduction

This chapter describes the deployment of the main survey and the initial organisation of response data. The collation of the invitation database is outlined in section 7.2 and the mechanics of its deployment is presented in section 7.3. Response rates and the demographic profile of those responses are analysed in section 7.4. Finally, cleansing of the data and initial creation of variables in SPSS is described in section 7.5 before the chapter is summarised in section 7.6.

The *SurveyMonkey* questionnaire used in the pilot study of chapter 6 was recreated in *Qualtrics* (due to a change in University provider) with the changes described in section 6.4 incorporated. The full text of the survey can be found in Appendix B.

This survey text was submitted to the University of York's ethics committee for review and approval was granted on 31<sup>st</sup> October 2016.

## 7.2 Invitation Database

A contact database was obtained with permission from an engineering software retailer. The database contained over 2,300 contacts from over 700 companies. The nature of the engineering software sold by the retailer and its geographic market led to the vast majority of the businesses being UK manufacturing businesses.

The database contained full names, email addresses and job titles. The list was cleansed of inappropriate organisations such as academic institutions and design consultancies with no manufacturing activity. Contacts with job titles indicating IT, sales, finance, HR, purchasing and CAD (Computer-Aided Design) functional disciplines were removed, leaving Chief Executive Officers, Managing Directors, and directors and managers from engineering and manufacturing disciplines.

To this refined database the author added approximately 50 of his own contacts. The final total of individuals invited to take part in the survey was 1,892 from 646 unique companies. Responses to the company name question (Q11) in the questionnaire would identify multiple responses from the same organisation.

## 7.3 Survey Deployment

Invitations to take part in the survey were sent to the contact list using a 'mail merge' approach from the author's university email account. The mail merge ensured an efficient delivery of the invitations and facilitated the inclusion of the invitees' first name in the salutation of the covering email.

The choice of using the author's university email account in preference to a personal or professional account ensured that the academic nature of the survey was emphasised in order to encourage participation. An invitation to make direct contact with the author was included in the covering emails in order that invitees' queries could be addressed and concerns allayed. 25 respondents made direct contact by email and this interaction did encourage participation that perhaps otherwise would not have been forthcoming.

The 1,892 invitations to take part in the questionnaire were sent and followed up in three phases:

- First request                      between 16/11/16 and 25/11/16
- Reminder                            between 29/11/16 and 4/12/16
- Final call                            between 17/12/16 and 18/12/16

The text of the three covering emails are reproduced in Appendix B prior to the full text of the survey.

## 7.4 Survey Response

Of the 1,892 invitations to take part there were 191 emails that failed to reach their destination (i.e. deflected by company servers) and eight companies directly responded to state that they had in fact no manufacturing facilities. This reduced the total number of valid invites to 1,701 from 638 unique companies.

192 responses were received representing a response rate of **11.3%** (192/1701). Of these responses 39 were incomplete and a further nine were duplicates from the same company, leaving a total of 144 complete and unique responses. From a company perspective this represents a response rate of **22.6%** (144/638).

Although participants were asked to provide their company name on an *optional* basis a very high proportion actually provided this information, and in fact all respondents providing otherwise complete questionnaires did provide their company name. This provides confidence that 144 complete responses are from unique companies. There were nine complete responses representing the second or third response from the same company. Where this occurred the response that was selected for inclusion in the set of 144 *complete and unique* responses was based on the most senior of the individuals responding.

It was observed that where surveys were incomplete, respondents had largely simply stopped part way through the questionnaire rather than sporadically failing to answer individual questions. This indicates a level of respondent fatigue, but also suggests that those questions that were completed are actually valid for that respondent.

Table 41 presents the breakdown of survey responses by extent of question completion.

	Qty	%
Unique & Complete	144	75.0
Unique & Complete up to and including Q26	1	0.5
Unique & Complete up to and including Q24	13	6.8
Unique & Complete up to and including Q15	3	1.6
Unique & Complete up to and including Q13	11	5.7
Unique & Complete up to and including Q11	3	1.6
Duplicate & Complete	9	4.7
Duplicate & Incomplete	8	4.2
<b>Total</b>	<b>192</b>	<b>100.0</b>

**Table 41 – Completeness of Survey Response**

The 14 responses that are complete up to and including question 24 have been included in the statistical analysis that follows in chapter 8, because these responses do have value for those sections that have been answered. Questions that have not been answered for these 14 responses cover areas including ambidexterity, continuous improvement, training & absorptive capacity.

The resulting 158 participants satisfy the target sample size of approximately 150 proposed in chapter 4.

Tables 42 to 55 characterise the demographic and personal profiles of the respondents.

## 7.4.1 Organisation Profile

Tables 42 to 44 characterise the structure of the respondent's organisation. Only one of the businesses is government-owned, with the majority responses (77%) from privately owned firms. An overwhelming proportion of responses (97%) are from organisations that have a dedicated manufacturing facility – this is important as senior management teams should have the autonomy required to set and implement strategy in this scenario. Potentially countering this autonomy is the influence of parent organisations in just under half of cases (46%). The location of parent companies in those 73 cases is focussed in the UK, the EU and the US, with only 15% in other countries.

Ownership	Frequency	Percent
Publicly traded	35	22.2
Privately owned	122	77.2
Government	1	0.6
<b>Total</b>	<b>158</b>	<b>100.0</b>

Table 42 – Survey Q1 Ownership Structure Response

Organisation Structure	Frequency	Percent
The business has its own manufacturing facility and is not a subsidiary of a larger group of companies.	85	53.8
The business has its own manufacturing facility, and is a subsidiary of a larger group of companies.	68	43.0
The business is a subsidiary of a larger group of companies and shares its manufacturing facility with some or all of those companies.	5	3.2
<b>Total</b>	<b>158</b>	<b>100.0</b>

Table 43 – Survey Q2 Organisation Structure Response

Parent Office Location	Frequency	Percent
UK	18	24.7
EU	22	30.1
US	22	30.1
Canada	1	1.4
China	1	1.4
India	2	2.7
Japan	5	6.8
Singapore	1	1.4
South Africa	1	1.4
<b>Total</b>	<b>73</b>	<b>100.0</b>

Table 44 – Survey Q2A Parent Office Location Response

Tables 45 to 47 reflect the range of sizes of respondent organisation in terms of the number of group and company employees and sales revenue. The number of *company* employees (table 46) is most relevant to the local manufacturing organisation and is normally spread across the employee quantity groups, with the majority (77%) in the SME range (< 250 employees). Sales revenue frequencies, unsurprisingly, mirror the distribution of company employees.

<b>Group Employees</b>	Frequency	Percent
1 - 250	6	8.2
251 - 1000	16	21.9
1001 - 5000	19	26.0
More than 5000	32	43.8
<b>Total</b>	<b>73</b>	<b>100.0</b>

**Table 45 – Survey Q2B Group Employees Response**

<b>Company Employees</b>	Frequency	Percent
1 -10	3	1.9
11 - 50	31	19.6
51 - 250	87	55.1
251 - 1000	24	15.2
1001 - 5000	10	6.3
More than 5000	3	1.9
<b>Total</b>	<b>158</b>	<b>100.0</b>

**Table 46 – Survey Q3 Company Employees Response**

<b>Sales Revenue</b>		Frequency	Percent	Valid Percent
<b>Valid</b>	< £10m	52	32.9	33.5
	£11m - £50m	66	41.8	42.6
	£51m - £100m	13	8.2	8.4
	£101m - £500m	19	12.0	12.3
	> £500m	5	3.2	3.2
	<b>Total</b>	<b>155</b>	<b>98.1</b>	<b>100.0</b>
<b>Missing</b>		3	1.9	
<b>Total</b>		<b>158</b>	<b>100.0</b>	

**Table 47 – Survey Q4 Sales Revenue Response**



Table 48 indicates the level of respondent organisations' R&D investment. Responses are again spread across the response categories and this may be related to the different industrial sector norms. Respondent industry categories are shown in table 49. Examination of responses in the 'other, please specify' category have been successfully categorised into two new categories 'Process Engineering' and 'Multi-Sector'. This was achieved by examining individual respondents' company websites.

R&D Investment		Frequency	Percent	Valid Percent
<b>Valid</b>	Less than 0.5%	15	9.5	9.6
	0.5% to 1.0%	29	18.4	18.5
	1% to 2%	37	23.4	23.6
	2% to 5%	40	25.3	25.5
	5% to 10%	25	15.8	15.9
	More than 10%	11	7.0	7.0
	<b>Total</b>	<b>157</b>	<b>99.4</b>	<b>100.0</b>
<b>Missing</b>	.	1	.6	
<b>Total</b>		<b>158</b>	<b>100.0</b>	

Table 48 – Survey Q5 R&D Investment Response

Company Industry Sector	Frequency	Percent
Agriculture		
Airlines & Aerospace	3	1.9
Automotive	10	6.3
Construction	32	20.3
Defence	3	1.9
Entertainment & Leisure	6	3.8
Food & Beverages	9	5.7
Government		
Healthcare & Pharmaceuticals	9	5.7
Retail & Consumer Durables	12	7.6
Telecommunications & Electronics	12	7.6
Transportation & Delivery	2	1.3
Utilities, Energy, and Extraction	33	20.9
<b>Process Engineering</b>	<b>19</b>	<b>12.0</b>
<b>Multi-Sector</b>	<b>8</b>	<b>5.1</b>
<b>Total</b>	<b>158</b>	<b>100.0</b>

Table 49 – Survey Q6 Company Industry Response

Table 50 shows the age profile of the respondent's businesses. It can be seen that the overwhelming majority are from mature businesses that have been in existence for more than 20 years. Business systems, processes and culture will be correspondingly well-established and any effects due to rapid organisational growth should not be present.

Age of Business	Frequency	Percent
< 5	2	1.3
5 - 10	2	1.3
11 - 15	4	2.5
16 - 20	8	5.1
> 20	142	89.9
<b>Total</b>	<b>158</b>	<b>100.0</b>

**Table 50 – Survey Q7 Age of Business Response**

Table 51 indicates the location of respondent's principal manufacturing facility. Locations entered under the 'other, please specify' category have been grouped into two new categories 'Europe' and 'Outside Europe'. The geographic profile reflects the area of operation of the software retailer from which the contact database was sourced.

Manufacturing Location	Frequency	Percent
England - South West		
England - South East	1	.6
England - London		
England - East	1	.6
England - East Midlands	19	12.0
England - West Midlands	10	6.3
England - Yorkshire And The Humber	50	31.6
England - North East	13	8.2
England - North West	34	21.5
Northern Ireland	3	1.9
Republic of Ireland		
Scotland	18	11.4
Wales	3	1.9
<i>Europe</i>	2	1.3
<i>Outside Europe</i>	4	2.5
<b>Total</b>	<b>158</b>	<b>100.0</b>

**Table 51 – Survey Q16 Manufacturing Facility Location Response**

Table 52 shows that there is a significant quantity of responses in each of the four manufacturing process type categories.

<b>Manufacturing Process Type</b>	Frequency	Percent
Make to Stock	16	10.1
Make to Order	88	55.7
Assemble to Order	18	11.4
Engineer to Order	36	22.8
<b>Total</b>	<b>158</b>	<b>100.0</b>

**Table 52 – Survey Q18 Manufacturing Process Type Response**

## 7.4.2 Respondent Profile

Tables 53 to 55 present the profile of the individual respondents. Over 50% of responses were received from company directors. Respondent functional discipline is limited to those disciplines targeted by the choice of invitees' job title. Several discipline responses in the 'other, please specify' category were focussed on new product development (NPD) and innovation and these have been grouped with the 'Engineering' category.

<b>Respondent Seniority</b>	Frequency	Percent
Director	82	51.9
Senior Manager	44	27.8
Manager	32	20.3
<b>Total</b>	<b>158</b>	<b>100.0</b>

**Table 53 – Survey Q8 Respondent Seniority Response**

<b>Respondent Discipline</b>	Frequency	Percent
General Management	58	36.7
Engineering, <i>NPD &amp; Innovation</i>	68	43.0
Manufacturing & Operations	32	20.3
<b>Total</b>	<b>158</b>	<b>100.0</b>

**Table 54 – Survey Q9 Respondent Discipline Response**

Table 55 indicates the length of time respondents have been employed by their current employer. In general individuals have a significant tenure with their organisations with over 70% having over 8 years' service.

Respondent Tenure	Frequency	Percent
< 1 year	8	5.1
1 - 3 years	18	11.4
4 - 7 years	20	12.7
8 - 15 years	33	20.9
> 15 years	79	50.0
<b>Total</b>	<b>158</b>	<b>100.0</b>

**Table 55 – Survey Q10 Respondent Tenure Response**

## 7.5 Data Manipulation

The raw response data was transferred from the *Qualtrics* survey tool and imported into IBM's SPSS statistical analysis software. In preparation for the analysis of chapter 8 the dataset in SPSS needed to be organised, parcelled and new variables created. This is described in the following three sections.

### 7.5.1 Data Organisation

The raw data imported into SPSS required the following cleansing and organisation:

- Superfluous variables were deleted (e.g. IP addresses).
- A variable was added to indicate degree of response completeness.
- Missing answers were coded in a consistent manner.
- Additional categories were added to Q6 (industry), Q9 (business discipline) and Q16 (manufacturing location) as described in sections 7.4.1 and 7.4.2.
- Qualtrics coding for reverse-coded questions does not successfully import into SPSS, therefore these answers required recoding in SPSS. This applied to questions within Q12 (environmental turbulence), Q15 (emergent strategy bias) and Q28 & Q29 (absorptive capacity).

## 7.5.2 Data Parcelling

Section 4.3.6.1 described the benefits of *parcelling* question sets into single measurable variables. This was achieved for the following questions by allocating a numeric value to each question response and creating a new SPSS variable by calculating the simple average for the question set.

- Q12 – Environmental Turbulence
- Q13 – Firm Performance
- Q14 – Innovation Propensity
- Q15 – Emergent Strategy Bias
- Q24 – Manufacturing Flexibility
- Q25 – Ambidexterity – Exploration (first six questions)
- Q25 – Ambidexterity – Exploitation (second six questions)
- Q26 – Continuous Improvement
- Q27 – Training
- Q28 – Potential Absorptive Capacity
- Q29 – Realised Absorptive Capacity

## 7.5.3 Variable Creation

The following new variables were created in SPSS to complete the required complement of OF-AF Gap observable variables to be used in the analysis in chapter 8. A number of these variables required polarity changes to ensure all nine variables resulted in the same expected polarity relationship with the OF-AF Gap construct. From table 9 in section 5.2.2.5, polarity changes were required for *Age of Assets*, *Asset Utilisation*, *Exploitation Domination* and *Operational Ambidexterity*. This was achieved by multiplying these variables by ‘-1’.

The **Age of Assets** variable was derived from responses to Q17. The respondents’ apportionment of their suite of equipment into the five age categories was converted into an aggregate Age of Assets value using the following formula (see section 5.2.3.2):

$$(( '<2yr' + ('3-5yr' \times 4) + ('6-10yr' \times 8) + ('11-20yr' \times 15.5) + ('>20yr' \times 25) ) / 100) \times (-1)$$

The **Asset Utilisation** variable was derived from responses to Q19. Category answers were converted to a series of ordinal values as follows (see section 5.2.3.1):

0%	→	- 100
1-5%	→	- 97.1
6-10%	→	- 92.6
11-20%	→	- 86.6
>20%	→	- 80

The **Product Portfolio Complexity** variable was created by combining answers to Q20 to Q23. Each of these four questions consisted of five graduated statements from which the respondent selected the most appropriate. The five responses to each of the four questions were coded by allocating values of 1 to 5. The Product Portfolio Complexity variable was created using a simple addition of these four response values (see section 5.2.3.9).

The two variables relating to ambidexterity – **Exploitation Domination** and **Operational Ambidexterity** – were created by combining the exploration and exploitation (parcelled) variables derived from the answers to Q25 (see sections 5.2.3.6 and 5.2.3.7).

$$\begin{aligned} \text{Exploitation Domination} &= (\text{Exploitation} - \text{Exploration}) \times (-1) \\ \text{Operational Ambidexterity} &= (|\text{Exploration} - \text{Exploitation}|) \times (-1) \end{aligned}$$

The **Operational Absorptive Capacity** variable was created by simply adding together the potential absorptive capacity and realised absorptive capacity (parcelled) variables derived from the answers to Q28 and Q29 (see section 5.2.3.5).

## 7.5.4 OF-AF Gap Item Summary

Table 56 summarises the resulting polarities of the nine variables that make up the OF-AF Gap construct to be used in the analysis of chapter 8. The nine variables' polarity from table 9 of section 5.2.2.5 are reproduced on the left of table 56. To ensure that all nine variables have the same expected polarity relationship with the OF-Gap construct – important for the EFA and CFA analysis in chapter 8 – four variables have had their polarities reversed and these are indicated by an (R) suffix.

For example, the expected polarity for *Asset Utilisation* is that a *lower* the value for this variable (i.e. younger assets) is expected to correspond to a *larger* OF-AF Gap. In order that all nine variables have the same polarity in the analysis, the *Asset Utilisation* responses are multiplied by  $-1$  so that a *greater* value for this reversed value corresponds with a larger OF-AF gap.

<b>Expected Item Polarities</b> (from table 9) (all correlating to <i>larger</i> OF-AF Gap)	<b>Polarities Used for Analysis</b> (all correlating to <i>larger</i> OF-AF Gap)
Less <b>Asset Utilisation</b>	<i>Greater</i> <b>Asset Utilisation (R)</b>
Younger <b>Age of Assets</b>	<i>Greater</i> <b>Age of Assets (R)</b>
More <b>Continuous Improvement</b>	More <b>Continuous Improvement</b>
More <b>Training</b>	More <b>Training</b>
Higher <b>Operational Absorptive Capacity</b>	Higher <b>Operational Absorptive Capacity</b>
Less <b>Exploitation Domination</b>	<i>Greater</i> <b>Exploitation Domination (R)</b>
Smaller <b>Operational Ambidexterity</b>	<i>Greater</i> <b>Operational Ambidexterity (R)</b>
More <b>Manufacturing Flexibility</b>	More <b>Manufacturing Flexibility</b>
More <b>Product Portfolio Complexity</b>	More <b>Product Portfolio Complexity</b>

Table 56 – OF-AF Gap Item Polarity

## 7.6 Chapter Summary

This chapter has described the deployment of the main survey questionnaire to 1,892 individuals in manufacturing businesses. The profile of individuals targeted followed the conclusions drawn from the pilot survey in chapter 6. Usable responses numbering 158 fulfil the sample size objectives of chapter 4.

The demographic profile of the respondent population has been discussed and the manipulation of raw Qualtrics data once imported to SPSS has been described.

The next chapter, chapter 8, presents the analysis of the main survey data.

## Chapter 8: Main Survey Analysis

This chapter describes the analysis of the responses to the main survey, the deployment of which was presented in chapter 7. Initial checks of data normality and reliability for individual variables are discussed in sections 8.1 and 8.2 respectively. Section 8.3 then reports on the final stages of the development of the OF-AF Gap scale originally proposed in section 4.3.6.1. The way the nine variables that comprise the new construct combine is examined using exploratory and confirmatory factor analysis. This reveals the OF-AF Gap scale's factor structure and its reliability and validity.

Having established the OF-AF Gap scale's structure, its relationship with the other main model variables is examined. Section 8.4 evaluates correlations between the OF-AF Gap, Environmental Turbulence, Innovation Propensity, Emergent Strategy Bias and Firm Performance, thereby testing the correlation hypotheses of section 3.2.2.1. Section 8.5 develops a structural equation model to evaluate regressions between these variables, thereby testing the causality hypotheses of section 3.2.2.2.

The chapter is summarised in section 8.6 before detailed discussion of the findings is presented in chapter 9.

### 8.1 Data Normality

#### 8.1.1 Normality Requirements

Field [227, pp168-9] identifies common misconceptions among researchers regarding the requirements for normality of data outcomes in quantitative research. To evaluate relationships between variables and model parameters – as this research aims to do – it is important that the *sample distribution* and *model residuals* are normally distributed. If data outcomes are normally distributed it is reasonable to assume that these requirements are met, but critically, the converse is not necessarily true.

*“... the assumption of normality tends to get translated as ‘your data need to be normally distributed’, even though that’s not really what it means.”*

[227, p169]



The Central Limit Theorem contends that if the sample size is sufficiently large researchers can assume normality of the sample distribution.

*“If you want to construct confidence intervals around [model] parameters, or compute significance tests relating to those parameters, then the assumption of normality matters in small samples, but because of the central limit theorem we don’t really need to worry about this assumption in larger samples.” [227, p172]*

The widely accepted sample size required to ensure that the central limit theorem applies is 30, however larger sample sizes (e.g. 100 or more) protect against distributions with significant outliers [227, p172]. With a sample size of 158 the central limit theorem can be seen to apply and the normality of data outcomes is therefore not critical in this research.

Notwithstanding the fact that normality of data outcomes is not critical, it is interesting to explore this characteristic of the survey data for each of the model variables.

## 8.1.2 Normality Evaluation

The data outcomes for the nine variables intended to define the new OF-AF Gap construct and the four main model variables (Environmental Turbulence, Innovation Propensity, Emergent Strategy Bias and Firm Performance) are assessed for normality in section 8.1.3. There are numerous graphical and numerical tests available to make this assessment.

Numerical tests such as *Kolmogorov-Smirnov* and *Shapiro-Wilk* offer a binary view of normality (i.e. ‘normal’ or ‘not normal’) by comparing the *p-value* of the test to 0.05 (> 0.05 implies a normal distribution). The *Shapiro-Wilk* test is more appropriate for small to medium sample sizes and will therefore be used in the evaluation [281, 282].

There are known issues in relying solely on such numeric evaluations however. In larger samples, results can be significant (i.e. < 0.05, implying non-normality) even when the scores are only slightly different from a normal distribution [227, p184]. For this reason it is recommended to use numerical tests in conjunction with graphical measures such as histograms and Q-Q plots [227, p188].

### 8.1.3 Normality Characteristics of Survey Data

The following sections present the normality characteristics of the four main model variables and the nine variables intended to define the new OF-AF Gap construct. As described above the numerical *Shapiro-Wilk* test is used in conjunction with graphical measures to ameliorate the propensity of the *Shapiro-Wilk* test to exaggerate ‘slightly non-normal’ aspects of the data.

It is also interesting to note that an apparent non-normal distribution of the whole sample can be explained by two (or more) normal distributions (distinguished by particular demographics) being combined into a single non-normal set [227, p169]. As will be seen below, there is evidence of this phenomenon in this research’s data set – for example, some variables with non-normal distributions across the whole data set, are shown to be comprised of normally distributed subsets of data when broken down by industry classification.

#### 8.1.3.1 Main Model Variable Normality

##### Environmental Turbulence

The *Shapiro-Wilk* test returns a p-value (Sig) of 0.708 indicating normality for the Environmental Turbulence variable data which is visually confirmed by histogram and Q-Q plot in figure 28.

Shapiro-Wilk	Statistic	df	Sig.
Environmental Turbulence	.994	158	.708

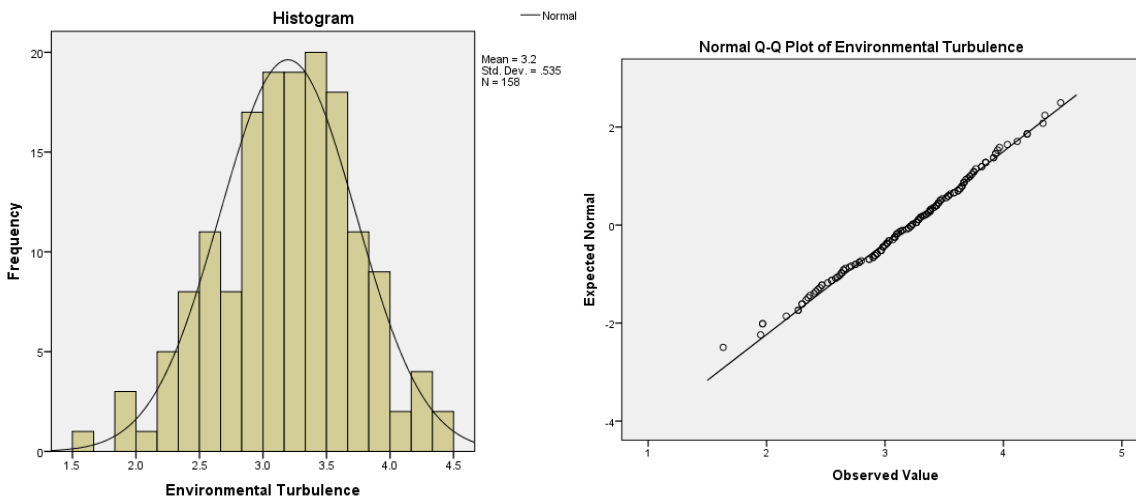


Figure 28 – Environmental Turbulence Normality Analysis

## Firm Performance

The *Shapiro-Wilk* test returns a p-value of 0.207 (Sig) indicating normality for this variable data which is visually confirmed by the histogram and Q-Q plot in figure 29.

Shapiro-Wilk	Statistic	df	Sig.
Firm Performance	.988	156	.207

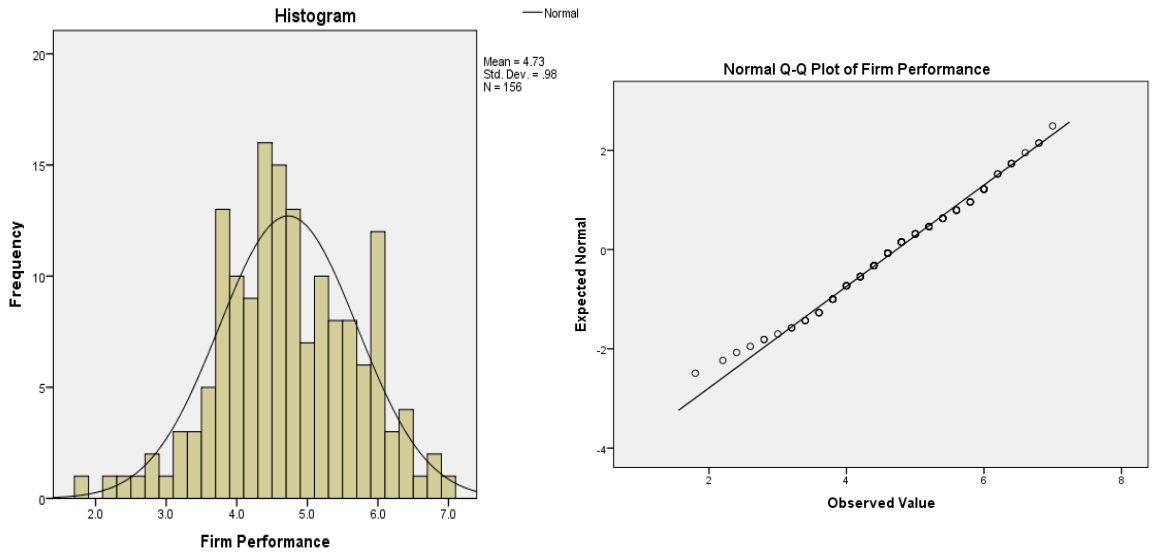


Figure 29 – Firm Performance Normality Analysis

## Innovation Propensity

The *Shapiro-Wilk* test returns a p-value (Sig) of 0.000 indicating non-normality for the Innovation Propensity variable data, and a degree of skewness can be seen in the histogram and Q-Q plot in figure 30.

Shapiro-Wilk	Statistic	df	Sig.
Innovation Propensity	.942	156	.000

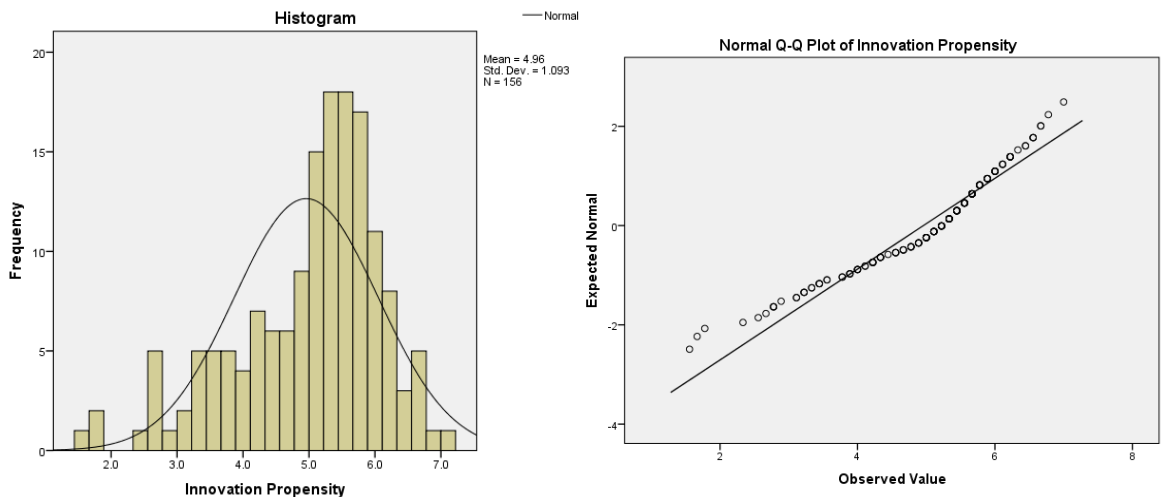


Figure 30 – Innovation Propensity Normality Analysis

If the innovation propensity data is split by industry, the underlying normality of these groups is revealed. Table 57 shows the *Shapiro-Wilk* p-value results for industry groups where there were more than six responses.

Industry (more than 6 responses)	Shapiro-Wilk p-value (sig)
Automotive (10)	.434
Construction (31)	.091
Food & Beverage (9)	.352
Healthcare (9)	.630
Retail (12)	.141
Telecoms (12)	.001
Utilities (33)	.069
Process Engineering (19)	.130
Multi-Sector (8)	.849

Table 57 – Innovation Propensity Normality Analysis – Industry Split

It can be seen from table 57 that with the exception of *Telecoms*, all groups' data are numerically evaluated as normal (p-value > 0.05).

### **Emergent Strategy Bias**

The *Shapiro-Wilk* test returns a p-value (Sig) of 0.001 indicating non-normality for the Emergent Strategy Bias variable data, and a similar degree of skewness to that of *Innovation Propensity* can be seen in the histogram and Q-Q plot of figure 31.

Shapiro-Wilk	Statistic	df	Sig.
Emergent Strategy Bias	.965	156	.001

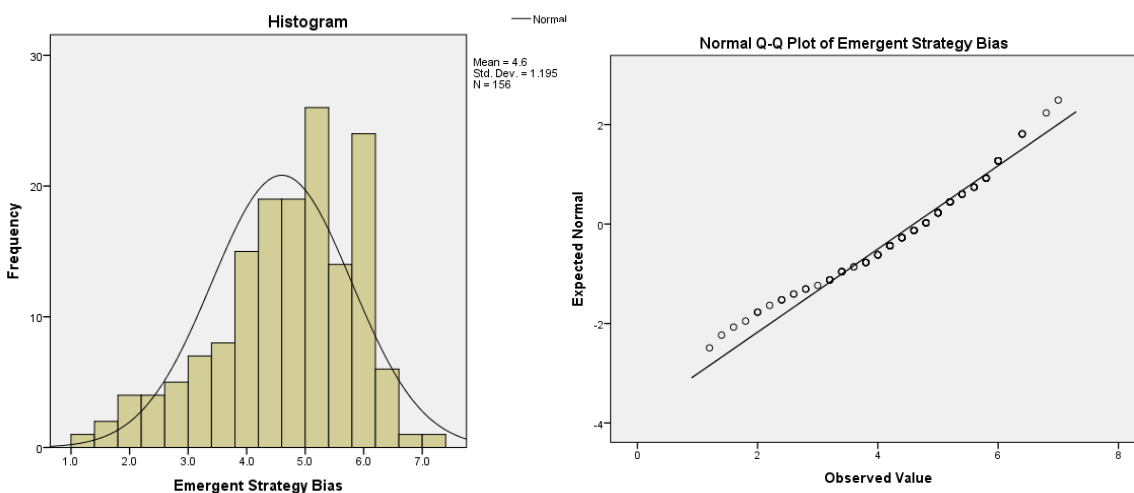


Figure 31 – Emergent Strategy Bias Normality Analysis

Again, if the Emergent Strategy Bias data is split by industry, the underlying normality of these groups is revealed. Table 58 shows the *Shapiro-Wilk* p-value results for industry groups where there were more than six responses.

Industry (more than 6 responses)	Shapiro-Wilk p-value (sig)
Automotive (10)	.134
Construction (31)	.037
Food & Beverage (9)	.822
Healthcare (9)	.442
Retail (12)	.764
Telecoms (12)	.258
Utilities (33)	.016
Process Engineering (19)	.840
Multi-Sector (8)	.162

Table 58 – Emergent Strategy Bias Normality Analysis – Industry Split

It can be seen from table 58 that with the exception of *Construction* and *Utilities*, all groups' data are numerically evaluated as normal (p-value > 0.05).

### 8.1.3.2 OF-AF Gap Variable Normality

#### Asset Utilisation

The *Shapiro-Wilk* test returns a p-value (Sig) of 0.000 indicating non-normality for this variable, and the ordinal nature of this variable makes visual assessment of normality from the histogram problematic. The Q-Q plot does not show significant non-normality.

Shapiro-Wilk	Statistic	df	Sig.
Asset Utilisation	.819	156	.000

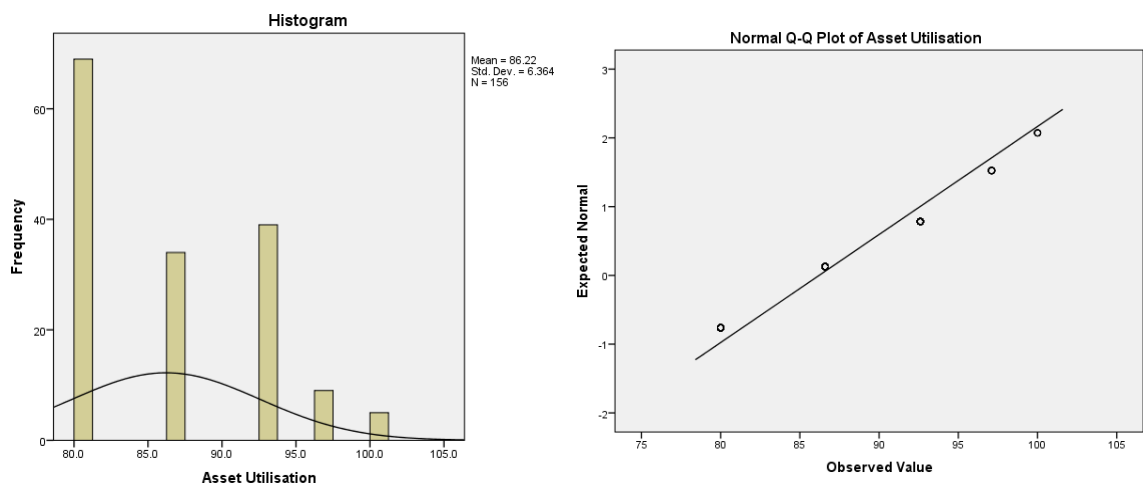


Figure 32 – Asset Utilisation Normality Analysis

## Age of Assets

The *Shapiro-Wilk* test returns a p-value (Sig) of 0.001 indicating non-normality for the Age of Assets variable data, and a degree of skewness can be seen in the histogram and Q-Q plot in figure 33.

Shapiro-Wilk	Statistic	df	Sig.
Age of Assets	.961	158	.000

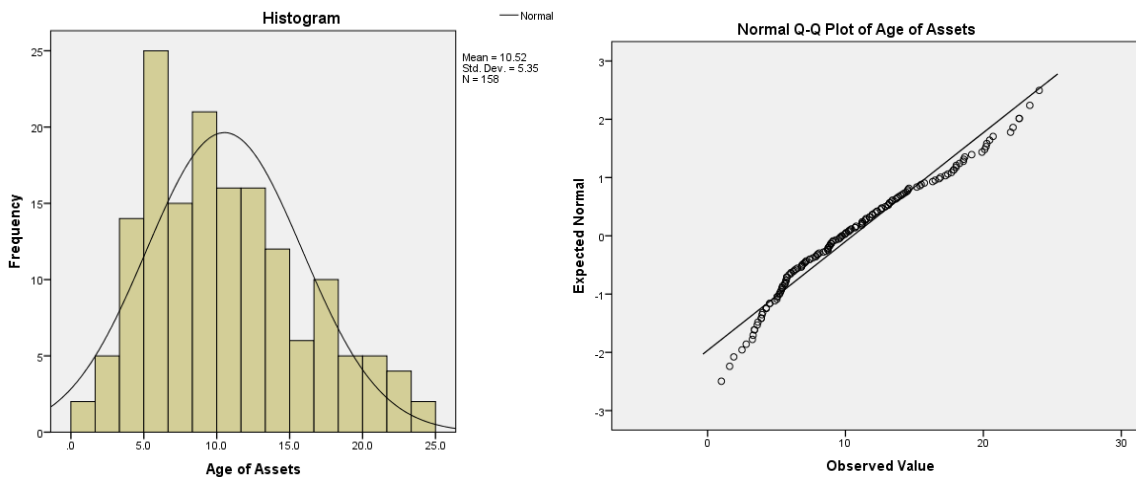


Figure 33 – Age of Assets Normality Analysis

If the Age of Assets data is split by industry, the underlying normality of these groups is revealed. Table 59 shows the *Shapiro-Wilk* p-value results for industry groups where there were more than six responses.

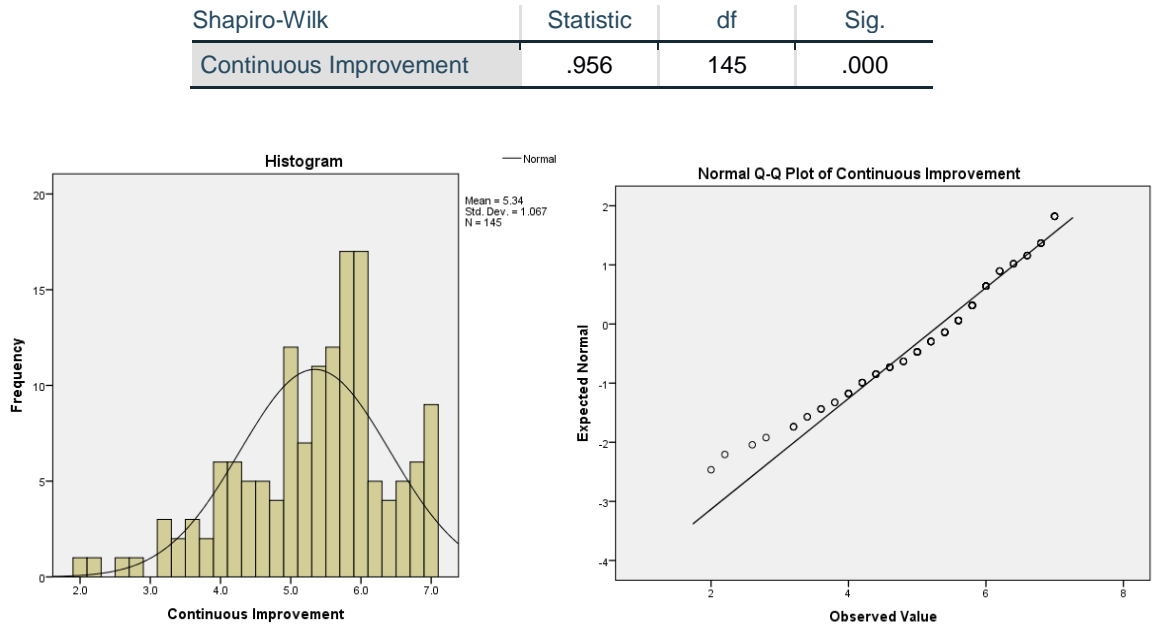
Industry (more than 6 responses)	Shapiro-Wilk p-value (sig)
Automotive (10)	.662
Construction (32)	.634
Food & Beverage (9)	.865
Healthcare (9)	.389
Retail (12)	.064
Telecoms (12)	.383
Utilities (33)	.200
Process Engineering (19)	.758
Multi-Sector (8)	.086

Table 59 – Age of Assets Normality Analysis – Industry Split

It can be seen from table 59 that all groups' data are numerically evaluated as normal (p-value > 0.05).

## Continuous Improvement

The *Shapiro-Wilk* test returns a p-value (Sig) of 0.000 indicating non-normality for the Continuous Improvement variable data, and a degree of skewness can be seen in the histogram and Q-Q plot in figure 34.



**Figure 34 – Continuous Improvement Normality Analysis**

If the Continuous Improvement data is split by industry, the underlying normality of these groups is revealed. Table 60 shows the *Shapiro-Wilk* p-value results for industry groups where there were more than six responses.

Industry (more than 6 responses)	Shapiro-Wilk p-value (sig)
Automotive (8)	.059
Construction (29)	.673
Food & Beverage (8)	.628
Healthcare (8)	.117
Retail (11)	.750
Telecoms (12)	.009
Utilities (28)	.158
Process Engineering (19)	.171
Multi-Sector (8)	.136

**Table 60 – Continuous Improvement Normality Analysis – Industry Split**

It can be seen from table 60 that with the exception of *Telecoms*, all groups' data are numerically evaluated as normal (p-value > 0.05).

## Training

The *Shapiro-Wilk* test returns a p-value (Sig) of 0.000 indicating non-normality for the Training variable data, and a degree of skewness can be seen in the histogram and Q-Q plot in figure 35.

Shapiro-Wilk	Statistic	df	Sig.
Training	.951	144	.000

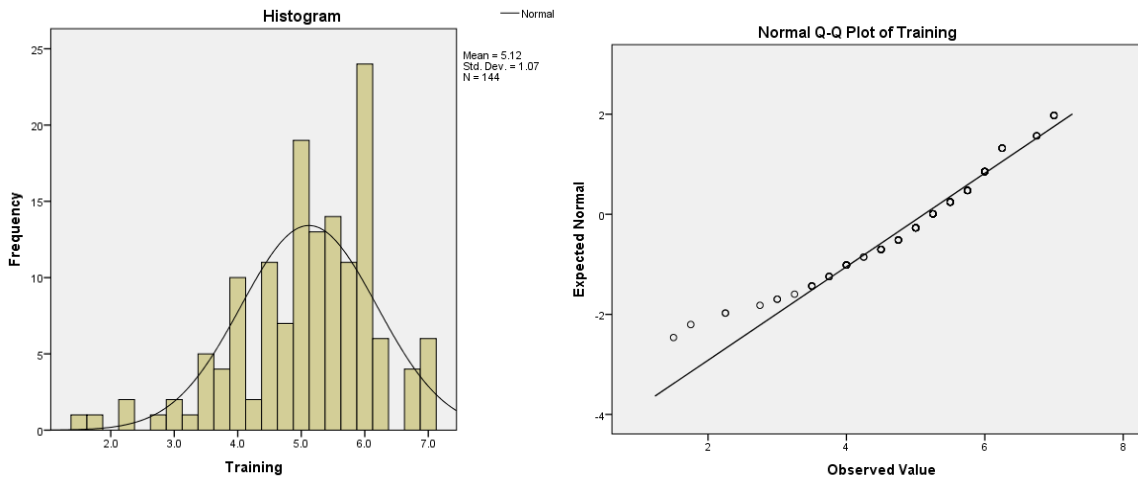


Figure 35 – Training Normality Analysis

If the Training data is split by industry, the underlying normality of these groups is revealed. Table 61 shows the *Shapiro-Wilk* p-value results for industry groups where there were more than six responses.

Industry (more than 6 responses)	Shapiro-Wilk p-value (sig)
Automotive (8)	.735
Construction (29)	.491
Food & Beverage (8)	.096
Healthcare (8)	.008
Retail (11)	.421
Telecoms (12)	.415
Utilities (28)	.248
Process Engineering (18)	.029
Multi-Sector (8)	.111

Table 61 – Training Normality Analysis – Industry Split

It can be seen from table 61 that with the exception of *Healthcare* and *Process Engineering*, all groups' data are numerically evaluated as normal (p-value > 0.05).



## Operational Absorptive Capacity

The *Shapiro-Wilk* test returns a p-value of 0.855 (Sig) indicating normality for the Operational Absorptive Capacity variable which is the sum of *potential* and *realised* absorptive capacity variables (see section 7.5.3). Histogram and Q-Q plot in figure 36.

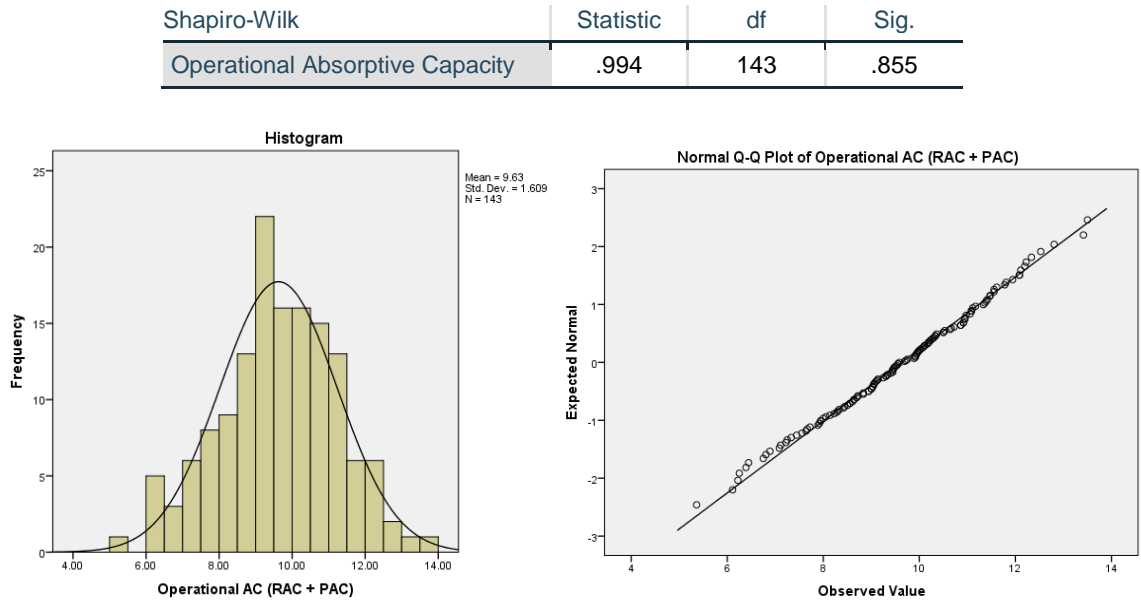


Figure 36 – Operational Absorptive Capacity Normality Analysis

## Operational Ambidexterity & Exploitation Domination

These variables are based on the difference between exploration and exploitation (see section 7.5.3). The *Shapiro-Wilk* test returns a p-value of 0.115 indicating normality for this dimension. Normality is confirmed by the histogram and Q-Q plot in figure 37.

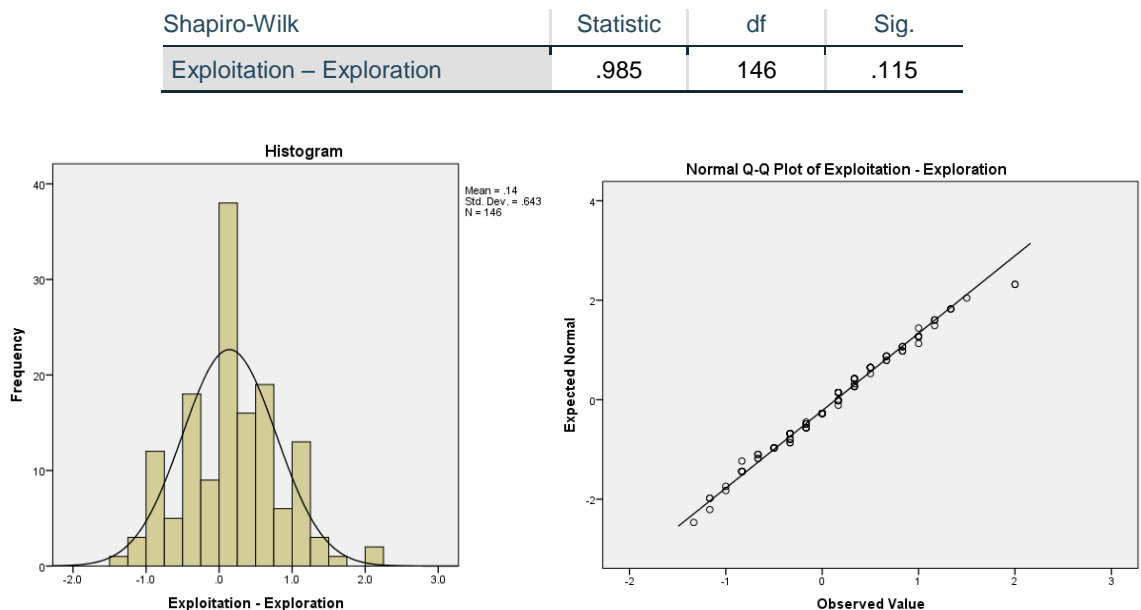
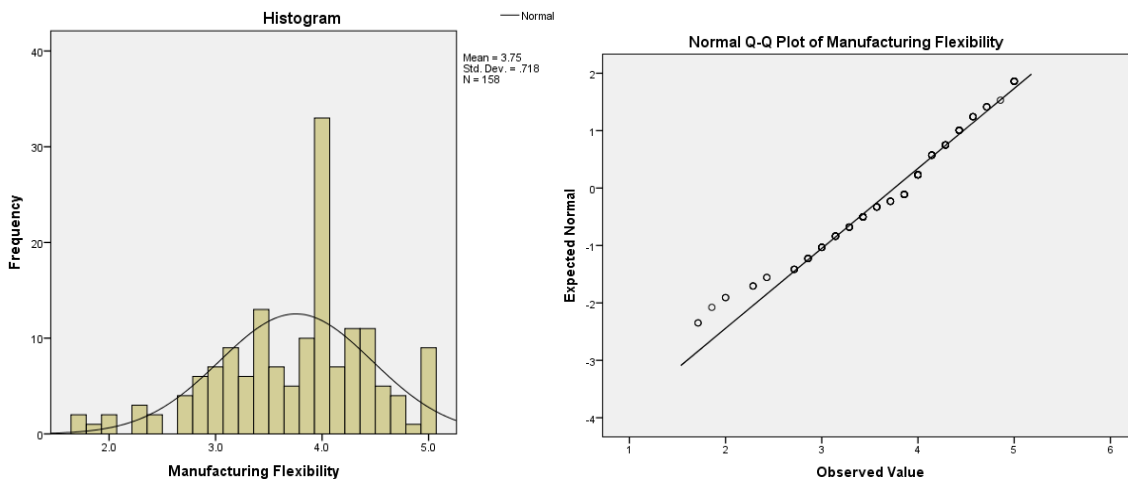


Figure 37 – Ambidexterity Normality Analysis

## Manufacturing Flexibility

The *Shapiro-Wilk* test returns a p-value (Sig) of 0.000 indicating non-normality for the Manufacturing Flexibility variable data, and a degree of skewness can be seen in the histogram and Q-Q plot in figure 38.

Shapiro-Wilk	Statistic	df	Sig.
Manufacturing Flexibility	.951	158	.000



**Figure 38 – Training Normality Analysis**

If the Manufacturing Flexibility data is split by industry, the underlying normality of these groups is revealed. Table 62 shows the *Shapiro-Wilk* p-value results for industry groups where there were more than six responses.

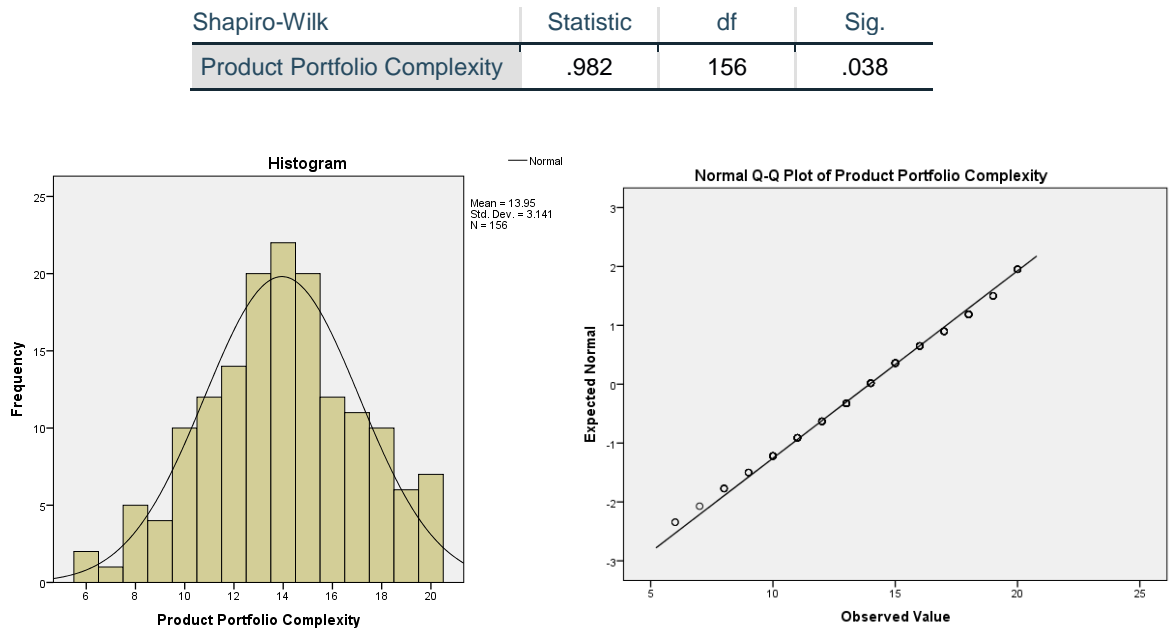
Industry (more than 6 responses)	Shapiro-Wilk p-value (sig)
Automotive (10)	.493
Construction (32)	.134
Food & Beverage (9)	.055
Healthcare (9)	.161
Retail (12)	.985
Telecoms (12)	.415
Utilities (33)	.191
Process Engineering (19)	.647
Multi-Sector (8)	.040

**Table 62 – Manufacturing Flexibility Normality Analysis – Industry Split**

It can be seen from table 62 that with the exception of *Multi-Sector*, all groups' data are numerically evaluated as normal (p-value > 0.05).

## **Product Portfolio Complexity**

The *Shapiro-Wilk* test returns a p-value (Sig) of 0.038 *just* indicating non-normality for the Product Portfolio Complexity variable data. However, the histogram and Q-Q plot in figure 39 indicate good normality for this variable.



**Figure 39 – Product Portfolio Normality Analysis**

### **8.1.3.3 Normality Assessment Summary**

As discussed in section 8.1.1, the normality of data outcomes is not critical to this research because the survey sample size allows the central limit theorem to take effect. However, the normality analysis presented in this section shows that there is in fact a high level of normality in the data outcomes, particularly when considered at the industry categorical level.

## **8.2 Variable Reliability**

All variables in this research’s survey have been measured using question sets selected from peer-reviewed literature and those sources report their scale reliabilities. These were presented in section 5.4 as variable unidimensionality was being

considered. This section reports Cronbach's coefficient of reliability (Cronbach's 'alpha' [231]) for the data outcomes in this research. Overall 'alpha' values should be greater than 0.7 with individual item correlations ideally greater than 0.3 [227, p709 & p713].

These reliability checks validate the source literatures' assertions of reliability with a different survey deployment, while also providing confidence in the unidimensionality of the OF-AF Gap variables – important in the justification for parcelling item scores to simplify analysis (see section 4.3.6.1).

## 8.2.1 Main Model Variable Reliability

### Environmental Turbulence

Table 63 shows the reliability analysis for the Environmental Turbulence variable question set responses. A Cronbach Alpha of 0.735 meets the generally accepted minimum of 0.7. There are three questions with slightly low individual correlations at around 0.2, but one question that appears problematic with an individual correlation of only 0.043. Excluding this question only marginally improves the overall alpha, so the question set has been left unaltered to maintain consistency with the source literature.

Cronbach's Alpha	N of Items	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
.735	11		
In our kind of business, customers' product preferences change over time		.320	.724
Our customers tend to look for new products all the time		.506	.698
Sometimes our customers are price sensitive, but on other occasions price is relatively unimportant		.174	.748
We are witnessing demand for our products and services from customers who never bought them before		.205	.739
New customers tend to have product-related needs that are different from those of our existing customers		.340	.722
We cater to similar customers to those we have in the past (R)		.043	.756
The technology in our industry is changing rapidly		.675	.670
Technological changes provide big opportunities in our industry		.612	.688
It is very difficult to forecast where the technology in our industry will be in the next two to three years		.223	.736
A large number of new product ideas have been made possible through technological breakthroughs in our industry		.606	.683
Technological developments in our industry are relatively minor (R)		.538	.692

Table 63 – Environmental Turbulence Reliability Analysis

## **Firm Performance**

Table 64 shows the reliability analysis for the Firm Performance variable question set responses. An alpha of 0.792 and individual correlations well above 0.3 show good reliability of this variable.

Cronbach's Alpha	N of Items		
.792	5		
		Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Productivity		.595	.748
Profitability		.593	.746
Market share of major product or product line		.665	.720
Growth rate in unit sales		.546	.761
Ability to produce a range of products		.477	.786

**Table 64 – Firm Performance Reliability Analysis**

## **Innovation Propensity**

Table 65 shows the reliability analysis for the Innovation Propensity variable question set responses. An alpha of 0.896 and individual correlations well above 0.3 show good reliability of this variable.

Cronbach's Alpha	N of Items		
.896	9		
		Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Innovation is an underlying culture and not just a word		.649	.886
Our business model is premised on the basis of strategic intent		.663	.886
Our senior managers are able to effectively cascade the innovation message throughout the organisation		.755	.877
We have an innovation vision that is aligned with projects, platforms, or initiatives		.767	.876
This organisation's management team is diverse in their thinking in that they have different views as to how things should be done		.426	.902
There is a coherent set of innovation goals and objectives that have been articulated		.763	.876
Innovation is a core value in this organisation		.773	.876
We have continuous strategic initiatives aimed at gaining a competitive advantage		.786	.875
Our strategic planning process is opportunity oriented as opposed to process oriented		.366	.906

**Table 65 – Innovation Propensity Reliability Analysis**

### **Emergent Strategy Bias**

Table 66 shows the reliability analysis for the Emergent Strategy Bias variable question set responses. An alpha of 0.855 and individual correlations well above 0.3 show good reliability of this variable.

Cronbach's Alpha	N of Items	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
.855	5		
We typically don't know what the content of our business strategy should be until we engage in some trial and error actions (R)		.590	.846
My business unit's strategy is carefully planned and well understood before any significant competitive actions are taken		.758	.804
Formal strategic plans serve as the basis for our competitive actions		.758	.802
My business unit's strategy is typically not planned in advance but, rather, emerges over time (R)		.588	.848
Competitive strategy for my business unit typically results from a formal business planning process		.670	.825

**Table 66 – Emergent Strategy Bias Reliability Analysis**

### **8.2.2 OF-AF Gap Variable Reliability**

Asset Utilisation and Age of Asset variables are scale items with single questions and are inherently 'reliable'. Therefore an Alpha value is not calculated for these variables.

### **Continuous Improvement**

Table 67 shows the reliability analysis for the Continuous Improvement variable question set responses. An alpha of 0.888 and individual correlations well above 0.3 show good reliability of this variable.

Cronbach's Alpha	N of Items	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
.888	5		
We strive to continually improve all aspects of products and processes, rather than taking a static approach		.681	.875
We search for continued learning and improvement, after the installation of new equipment		.803	.848
Continuous improvement makes our performance a moving target, which is difficult for competitors to attack		.755	.859
We believe that improvement of a process is never complete; there is always room for more incremental improvement		.684	.874
Our organisation is not a static entity, but engages in dynamically changing itself to better serve its customers		.734	.863

**Table 67 – Continuous Improvement Reliability Analysis**

## **Training**

Table 68 shows the reliability analysis for the Training variable question set responses. An alpha of 0.898 and individual correlations well above 0.3 show good reliability of this variable.

Cronbach's Alpha	N of Items		
.898	4		
		Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted

**Table 68 – Training Reliability Analysis**

## **Operational Absorptive Capacity**

Operational Absorptive Capacity is constructed by adding potential and realised absorptive capacity variables together (see section 7.5.3). Tables 69 and 70 show the reliability analysis for these two sub-variables. Alpha values of 0.770 and 0.881 are sufficiently high. All individual correlations are well above 0.3 with the exception of one question in the potential absorptive capacity set which is slightly low at 0.232. The question set has been left unaltered to maintain consistency with the source literature.

Cronbach's Alpha	N of Items		
.770	9		
		Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted

**Table 69 – Potential Absorptive Capacity Analysis**

Cronbach's Alpha	N of Items		
.881	12		
		Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Our business unit regularly considers the consequences of changing market demands in terms of new products & services		.613	.870
Employees record and store newly acquired knowledge for future reference		.703	.864
Our business unit quickly recognizes the usefulness of new external knowledge to existing knowledge		.709	.865
Employees rarely share practical experiences (R)		.456	.880
We work hard to seize the opportunities for our business unit from new external knowledge		.648	.868
Our business unit periodically meets to discuss consequences of market trends and new product development		.484	.878
It is well known how activities within our business unit should be performed		.707	.866
Client complaints fall on deaf ears in our business unit (R)		.419	.881
Our business unit has a clear division of roles and responsibilities		.568	.873
We constantly consider how to better exploit knowledge		.740	.863
Our business unit has difficulty implementing new products and services (R)		.443	.881
Employees have a common language regarding our products and services		.531	.875

**Table 70 – Realised Absorptive Capacity Analysis**

### **Operational Ambidexterity & Exploitation Domination**

These variables are based on the difference between exploration and exploitation (see section 7.5.3). Tables 71 and 72 show the reliability analysis for these two sub-variables. Alpha values of 0.846 and 0.804 respectively are sufficiently high. All individual correlations are well above 0.3.

Cronbach's Alpha	N of Items		
.846	6		
		Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Bases its success on its ability to explore new operational technologies		.699	.806
Creates products or services that are innovative to the firm		.671	.815
Looks for creative ways to satisfy its customers' needs		.671	.816
Aggressively ventures into new product segments		.689	.810
Actively seeks new manufacturing technologies and systems		.650	.817
Actively targets new customer groups		.424	.857

**Table 71 – Exploration Reliability Analysis**



Cronbach's Alpha	N of Items		
.804	6		
		Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Commits to improve quality and lower cost		.637	.756
Continuously improves the reliability of its products and services		.655	.758
Increases the levels of automation in its operations		.460	.811
Constantly surveys existing customers' satisfaction		.438	.803
Fine-tunes operational activities to keep its current customers satisfied		.590	.770
Continuously improves existing operational processes		.702	.743

**Table 72 – Exploitation Reliability Analysis**

### **Manufacturing Flexibility**

Table 73 shows the reliability analysis for the Manufacturing Flexibility variable question set responses. An alpha of 0.884 and individual correlations well above 0.3 show good reliability of this variable.

Cronbach's Alpha	N of Items		
.884	7		
		Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Our firm can introduce new products efficiently		.632	.872
Our firm can implement many different product modifications		.667	.868
Our firm can implement product modifications efficiently		.684	.866
Our firm's manufacturing system can operate at many high and low production volumes		.663	.869
Our firm's manufacturing system can change production volumes efficiently		.693	.865
Our firm's manufacturing system can accommodate many different product mixes		.693	.866
Our firm's manufacturing system can change product mixes efficiently		.708	.863

**Table 73 – Manufacturing Flexibility Reliability Analysis**

### **Product Portfolio Complexity**

Table 74 shows the reliability analysis for the Product Portfolio Complexity variable question set responses. The alpha result of 0.650 is marginally low and this has been influenced by one question which has correspondingly marginally low item correlation

of 0.296. The question set has been left unaltered to maintain consistency with the source literature.

Cronbach's Alpha	N of Items		Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
.650	4			
<hr/>				
Product Portfolio Complexity: Product Complexity			.513	.524
Product Portfolio Complexity: Process Complexity			.571	.496
Product Portfolio Complexity: Core Technologies			.296	.704
Product Portfolio Complexity: Customer Interface			.401	.602

**Table 74 – Product Portfolio Complexity Reliability Analysis**

### 8.2.3 Variable Reliability Summary

The response data from the main model variables and OF-AF Gap variables have been analysed in this section for scale reliability. Table 75 summarises the coefficients of reliability (Cronbach alpha) presented above.

Variable		Alpha
Environmental Turbulence		.735
Firm Performance		.792
Innovation Propensity		.896
Emergent Strategy Bias		.855
Continuous Improvement		.888
Training		.898
Absorptive Capacity	Potential	.770
	Realised	.881
Ambidexterity	Exploration	.846
	Exploitation	.804
Manufacturing Flexibility		.884
Product Portfolio Complexity		.650

**Table 75 – Reliability Analysis Summary**

All variables deliver coefficients of reliability (Cronbach alpha) greater than 0.7 with the exception of Product Portfolio Complexity which is slightly less than the ideal at 0.65.

All individual questions had item correlations greater than 0.3 with the exception of four questions in the Environmental Turbulence variable, one question in the Potential

Absorptive Capacity variable and one question in the Product Portfolio Complexity variable. Omitting any or all of these questions had a negligible effect on the overall reliability of the variables and therefore the six questions have been retained in order to maintain consistency with the peer-reviewed literature from which the question sets were obtained.

Overall, good reliability of all survey variables was observed, reinforcing the results of the source literature and providing confidence in the unidimensionality of each variable.

### 8.3 OF-AF Gap Scale Analysis

This section examines the data outcomes for the nine variables anticipated to combine to form the new OF-AF Gap metric. The factor structure of the new variable is investigated using exploratory factor analysis (EFA) in section 8.3.1, and preliminary conclusions are summarised in section 8.3.2. This is followed by confirmatory factor analysis (CFA) to refine and confirm the conclusions drawn from the EFA in section 8.3.3. Finally, the criteria for successful creation of the new OF-AF Gap measure derived in section 4.3.6.1 are reviewed in section 8.3.4.

#### 8.3.1 Exploratory Factor Analysis

A check of the scale’s reliability is shown in table 76. This initially assumes the OF-AF Gap is unidimensional, that is, it has a single underlying factor.

Cronbach's Alpha	N of Items		
.483	9		
		Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Asset Utilisation		.072	.487
Age of Assets		.267	.580
Product Portfolio Complexity		.122	.504
Manufacturing Flexibility		.386	.452
Exploitation Domination		.262	.468
Operational Ambidexterity		.250	.477
Continuous Improvement		.653	.388
Training		.583	.401
Operational Absorptive Capacity		.503	.380

Table 76 – Initial OF-AF Gap Reliability Analysis

The overall coefficient of reliability (alpha) is low at 0.483 and there are a number of elements with item correlations less than 0.3. In particular, Asset Utilisation is very low at 0.072.

This suggests that the OF-AF Gap measure may be multi-factorial. This is investigated below using exploratory factor analysis (EFA) in SPSS following the EFA guidance in Field [227].

The first stage is to review the *correlation matrix* which examines inter-correlations between the nine items. This is shown in table 77.

	Asset Utilisation	Age of Assets	Training	Continuous Improvement	Manufacturing Flexibility	Product Portfolio Complexity	Operational Absorptive Capacity	Exploitation Domination	Operational Ambidexterity
Asset Utilisation	1.000	.082	.167	.137	.213	-.055	-.019	-.043	-.114
Age of Assets	.082	1.000	.316	.365	.166	-.015	.284	.265	.127
Training	.167	.316	1.000	.692	.380	.244	.644	.098	.184
Continuous Improvement	.137	.365	.692	1.000	.473	.309	.662	.104	.176
Manufacturing Flexibility	.213	.166	.380	.473	1.000	.128	.491	.077	.160
Product Portfolio Complexity	-.055	-.015	.244	.309	.128	1.000	.188	.112	.150
Operational Absorptive Capacity	-.019	.284	.644	.662	.491	.188	1.000	.107	.298
Exploitation Domination	-.043	.265	.098	.104	.077	.112	.107	1.000	.312
Operational Ambidexterity	-.114	.127	.184	.176	.160	.150	.298	.312	1.000

Determinant = .091

**Table 77 – Initial OF-AF Gap Item Correlation Matrix**

The first check to undertake is to ensure there are no correlations that are greater than 0.9 because this would indicate multicollinearity – items that are essentially measuring the same thing. The highest correlation is less than 0.7 so multicollinearity is not an issue and this is corroborated by the determinant of the matrix being greater than 0.00001 [227, p686 & p694].

The second test is to look at items that have no correlations greater than 0.3. This may indicate an item not measuring the same underlying dimension as the other eight, and

such items should be considered for exclusion [227, p685 & p694]. Asset Utilisation can be seen to have no correlations greater than 0.3 – the highest correlation being 0.213. This casts doubt on the value of including asset utilisation in the OF-AF Gap measure.

The next stage of the EFA is to examine the anti-image correlation matrix which helps to confirm adequate sampling for each of the variables. This is shown in table 78.

	Asset Utilisation	Age of Assets	Training	Continuous Improvement	Manufacturing Flexibility	Product Portfolio Complexity	Operational Absorptive Capacity	Exploitation Domination	Operational Ambidexterity
Asset Utilisation	.419 <sup>a</sup>	-.036	-.176	-.067	-.231	.098	.230	.030	.098
Age of Assets	-.036	.746 <sup>a</sup>	-.077	-.216	.042	.170	-.030	-.250	-.002
Training	-.176	-.077	.800 <sup>a</sup>	-.384	.048	-.084	-.352	-.001	-.010
Continuous Improvement	-.067	-.216	-.384	.785 <sup>a</sup>	-.187	-.237	-.315	.029	.050
Manufacturing Flexibility	-.231	.042	.048	-.187	.805 <sup>a</sup>	.001	-.286	-.028	-.042
Product Portfolio Complexity	.098	.170	-.084	-.237	.001	.668 <sup>a</sup>	.074	-.092	-.078
Operational Absorptive Capacity	.230	-.030	-.352	-.315	-.286	.074	.765 <sup>a</sup>	.039	-.191
Exploitation Domination	.030	-.250	-.001	.029	-.028	-.092	.039	.592 <sup>a</sup>	-.276
Operational Ambidexterity	.098	-.002	-.010	.050	-.042	-.078	-.191	-.276	.711 <sup>a</sup>

a. Measures of Sampling Adequacy (MSA)

**Table 78 – Initial OF-AF Gap Anti-Image Correlation Matrix**

The test relating to the anti-image correlation matrix is that the values on the diagonal should be greater than 0.5 for there to be adequate sampling for that item [227, p695]. Table 78 shows all diagonal values to be significantly greater than 0.5 with the exception of Asset Utilisation which is only 0.419.

The low item correlation in the reliability analysis of table 76, coupled with the lack of individual correlations with other items in table 77, and the insufficient sampling adequacy in table 78 leads to the conclusion that **Asset Utilisation** should be **excluded** from the OF-AF Gap item group, and therefore from the rest of this chapter's analysis. The removal of this variable is discussed in more detail in chapter 9.

The correlation and anti-image correlation matrices are reproduced in tables 79 and 80 respectively, this time excluding the *Asset Utilisation* item.

	Age of Assets	Training	Continuous Improvement	Manufacturing Flexibility	Product Portfolio Complexity	Operational Absorptive Capacity	Exploitation Domination	Operational Ambidexterity
Age of Assets	1.000	.316	.365	.166	-.015	.284	.265	.127
Training	.316	1.000	.692	.380	.244	.644	.098	.184
Continuous Improvement	.365	.692	1.000	.473	.309	.662	.104	.176
Manufacturing Flexibility	.166	.380	.473	1.000	.128	.491	.077	.160
Product Portfolio Complexity	-.015	.244	.309	.128	1.000	.188	.112	.150
Operational Absorptive Capacity	.284	.644	.662	.491	.188	1.000	.107	.298
Exploitation Domination	.265	.098	.104	.077	.112	.107	1.000	.312
Operational Ambidexterity	.127	.184	.176	.160	.150	.298	.312	1.000

Determinant = .106

**Table 79 – Final OF-AF Gap Item Correlation Matrix**

	Age of Assets	Training	Continuous Improvement	Manufacturing Flexibility	Product Portfolio Complexity	Operational Absorptive Capacity	Exploitation Domination	Operational Ambidexterity
Age of Assets	<b>.741<sup>a</sup></b>	-.085	-.219	.034	.175	-.022	-.249	.002
Training	-.085	<b>.816<sup>a</sup></b>	-.403	.008	-.068	-.325	.005	.007
Continuous Improvement	-.219	-.403	<b>.776<sup>a</sup></b>	-.208	-.232	-.309	.031	.057
Manufacturing Flexibility	.034	.008	-.208	<b>.865<sup>a</sup></b>	.024	-.246	-.021	-.020
Product Portfolio Complexity	.175	-.068	-.232	.024	<b>.689<sup>a</sup></b>	.053	-.096	-.089
Operational Absorptive Capacity	-.022	-.325	-.309	-.246	.053	<b>.806<sup>a</sup></b>	.033	-.221
Exploitation Domination	-.249	.005	.031	-.021	-.096	.033	<b>.588<sup>a</sup></b>	-.281
Operational Ambidexterity	.002	.007	.057	-.020	-.089	-.221	-.281	<b>.693<sup>a</sup></b>

a. Measures of Sampling Adequacy (MSA)

**Table 80 – Final OF-AF Gap Anti-Image Correlation Matrix**

Table 79 shows that all of the remaining eight items have a correlation greater than 0.3 with at least one other item. Table 80 shows all eight items have adequate sampling measures of significantly greater than 0.5.

*Kaiser-Meyer-Olkin Measure of Sampling Adequacy* and *Bartlett's Test of Sphericity* are further tests that can be used to confirm sampling acceptability. The *Kaiser-Meyer-Olkin* test returns a value of 0.779 which according to Hutcheson & Sofroniou ranks close to 'meritorious' [283]. The results of *Bartlett's* test is shown in table 81.

Bartlett's Test of Sphericity	Approx. Chi-Square	311.331
	df	28
	Sig.	.000

**Table 81 – Bartlett's Test**

For sampling adequacy to be satisfactory Bartlett's test must return a significant result with the 'sig' value less than 0.01 – which in this case it is.

The next stage of the exploratory factor analysis is to extract factors and examine the significance of the contribution of each of those factors. Table 82 presents the variance associated with the factors extracted using generalised least squares extraction.

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	3.113	38.910	38.910	1.432	17.902	17.902	1.149
2	1.229	15.360	54.270	2.198	27.479	45.381	2.594
3	1.028	12.849	67.120	.754	9.430	54.811	1.183
4	.825	10.316	77.436				
5	.663	8.293	85.728				
6	.534	6.679	92.407				
7	.324	4.051	96.458				
8	.283	3.542	100.000				

**Table 82 – Factor Extraction Variance**

Kaiser's criterion [284] suggests factors with eigenvalues greater than 1 should be retained. Table 82 indicates three factors with eigenvalues above this level. Therefore the OF-AF Gap can be considered to consist of three factors.

Having extracted three factors the correlations between variables are examined again. The original correlations of table 79 are reproduced in table 83 with the effect of the factor extraction accounted for. The differences between the correlations before and after extraction are called the *residuals* and are presented in the bottom half of table 83. Generally the residuals should be 'low' for the factor extraction to represent a 'good' fit to the original data. The established criteria is that the "*percentage of 'non-redundant residuals with absolute values greater than 0.05' should be less than 50% and the smaller the better*" [227, p700].

		Age of Assets	Training	Continuous Improvement	Manufacturing Flexibility	Product Portfolio Complexity	Operational Absorptive Capacity	Exploitation Domination	Operational Ambidexterity
<b>Reproduced Correlations</b>	Age of Assets	.999 <sup>a</sup>	.316	.365	.166	-.015	.284	.265	.127
	Training	.316	.637 <sup>a</sup>	.692	.436	.242	.635	.095	.185
	Continuous Improvement	.365	.692	.753 <sup>a</sup>	.471	.256	.684	.099	.176
	Manufacturing Flexibility	.166	.436	.471	.304 <sup>a</sup>	.179	.444	.069	.166
	Product Portfolio Complexity	-.015	.242	.256	.179	.124 <sup>a</sup>	.260	.036	.149
	Operational Absorptive Capacity	.284	.635	.684	.444	.260	.653 <sup>a</sup>	.134	.296
	Exploitation Domination	.265	.095	.099	.069	.036	.134	.184 <sup>a</sup>	.313
	Operational Ambidexterity	.127	.185	.176	.166	.149	.296	.313	.731 <sup>a</sup>
	<b>Residuals<sup>b</sup></b>	Age of Assets		.000	.000	.000	.000	.000	.000
Training		.000		.001	-.056	.002	.009	.003	.000
Continuous Improvement		.000	.001		.002	.053	-.023	.005	.001
Manufacturing Flexibility		.000	-.056	.002		-.051	.047	.008	-.006
Product Portfolio Complexity		.000	.002	.053	-.051		-.073	.076	.001
Operational Absorptive Capacity		.000	.009	-.023	.047	-.073		-.026	.002
Exploitation Domination		.000	.003	.005	.008	.076	-.026		-.002
Operational Ambidexterity		.000	.000	.001	-.006	.001	.002	-.002	

Extraction Method: Generalized Least Squares.

a. Reproduced communalities

b. Residuals are computed between observed and reproduced correlations. There are 5 (17.0%) non-redundant residuals with absolute values greater than 0.05.

**Table 83 – Reproduced Correlations & Residuals**



Table 83 shows that the number of non-redundant residuals is five (17%) and therefore the three factor extraction adequately fits the original data.

The conclusion of the EFA process is the rotated factor loading matrix shown in table 84. Orthogonal rotation methods such as *varimax* are recommended as a first approach [227, p681]. The table indicates the deduced loadings of the eight variables onto the three extracted factors. Loadings less than 0.3 are excluded [227, p692].

**Varimax Rotated Matrix**

	Factor		
	1	2	3
Operational Absorptive Capacity	.775		
Continuous Improvement	.845		
Training	.780		
Manufacturing Flexibility	.542		
Product Portfolio Complexity	.319		
Exploitation Domination		.370	
Operational Ambidexterity		.839	
Age of Assets			.968

Extraction Method: Generalized Least Squares.  
Rotation Method: Varimax.

**Table 84 – Rotated Factor Matrix**

In order to check the stability of the factor extraction the EFA process was repeated with several other factor extraction and matrix rotation combinations that are available in SPSS. The results are shown in tables 85 to 87.

Generalised Least Squares Extraction	Oblimin Pattern Matrix			Varimax Rotated Matrix		
	1	2	3	1	2	3
Operational Absorptive Capacity	.774			.775		
Continuous Improvement	.863			.845		
Training	.795			.780		
Manufacturing Flexibility	.550			.542		
Product Portfolio Complexity	.324			.319		
Exploitation Domination		.377			.370	
Operational Ambidexterity		.848			.839	
Age of Assets			.949			.968

**Table 85 – Factor Extraction using Generalised Least Squares**

Unweighted Least Squares Extraction	Oblimin Pattern Matrix			Varimax Rotated Matrix		
	1	2	3	1	2	3
Operational Absorptive Capacity	.784			.780		
Continuous Improvement	.883			.851		
Training	.789			.765		
Manufacturing Flexibility	.542			.532		
Product Portfolio Complexity	.285			.296		
Exploitation Domination		.466			.451	
Operational Ambidexterity		.695			.691	
Age of Assets			.942			.969

Table 86 – Factor Extraction using Unweighted Least Squares

Maximum Likelihood Extraction	Oblimin Pattern Matrix			Varimax Rotated Matrix		
	1	2	3	1	2	3
Operational Absorptive Capacity	.767			.768		
Continuous Improvement	.852			.834		
Training	.790			.775		
Manufacturing Flexibility	.548			.539		
Product Portfolio Complexity	.328			.325		
Exploitation Domination		.307			.311	
Operational Ambidexterity		1.003			.984	
Age of Assets			.961			.978

Table 87 – Factor Extraction using Maximum Likelihood

It can be seen from tables 85 to 87 that for all six combinations of extraction method and rotation method the resulting factor structure is identical with very similar factor loadings. This provides confidence that the factor structure that has been developed is robust and stable.

### 8.3.2 Factor Structure Review

Exploratory Factor Analysis has revealed that of the nine original items proposed in chapter 5 to fully describe the new OF-AF Gap construct, *Asset Utilisation* should be removed as it has been found to be an unreliable component. Subsequent factor extraction (by several methods) has resulted in the conclusion that the construct is comprised of three distinct factors on which the eight remaining items load.

The first factor combines five of the eight scale items – Absorptive Capacity, Continuous Improvement, Training, Manufacturing Flexibility and Product Portfolio Complexity. Absorptive Capacity, Continuous Improvement and Training reflect aspects of individual and organisational *learning*, and Manufacturing Flexibility and Product Portfolio Complexity reflect aspects of the manufacturing unit’s *flexibility*. This factor will therefore be labelled **Learning & Flexibility** in the analysis that follows.

The second factor combines the two items relating to the ambidexterity profile of the business – Exploitation Domination and Operational Ambidexterity. This factor will therefore be labelled **Ambidexterity** in the analysis that follows.

The third factor *comprises a single factor – Age of Assets*.

The factor structure revealed by the exploratory analysis is refined and confirmed using confirmatory factor analysis in the next section.

### 8.3.3 Confirmatory Factor Analysis

Confirmatory factor analysis (CFA) takes the preliminary factor structure arising from the exploratory analysis and refines and confirms its quality. CFA has been undertaken in this research by creating a structural equation model in IBM’s AMOS software. The quality of the model has been assessed by selecting a series of goodness-of-fit indices from the wide range available in the software. This selection has been guided by recommendations in Byrne [233, p107].

Table 88 describes the three groups of goodness-of-fit indices selected for use.

<b>CMIN Group</b>	CMIN/DF	The minimum model discrepancy divided by the degrees of freedom. The lower value the better and a value < 2 is recommended for an acceptable fit [285, p641].
	P	P is a “p value” for testing the hypothesis that the model fits perfectly in the population. So ideally should be > 0.05 [233, p76].
<b>Baseline Comparison Group</b>	NFI	Normalised Fit Index ranging between 0 and 1, with 1 representing a ‘perfect’ fit. Values > 0.9 deemed acceptable [233, p78] [285, p650].
	CFI	Comparative Fit Index ranging between 0 and 1, with 1 representing a ‘perfect’ fit. Values > 0.95 deemed acceptable [233, p79].
<b>RMSE Group</b>	RMSEA	Root Mean Square Error of Approximation. Lower values are better with values between 0.05 and 0.08 deemed ‘good’ [233, p80] [285, p644].
	PCLOSE	Probability that the RMSEA value is < 0.05. Values approaching and ideally > 0.5 deemed acceptable [233, p81].

Table 88 – Goodness-of-Fit Indices

A structural equation model was created in AMOS in line with the factor structure revealed in section 8.3.2. The model was analysed and the resulting regressions and goodness of fit indices are shown in figure 40.

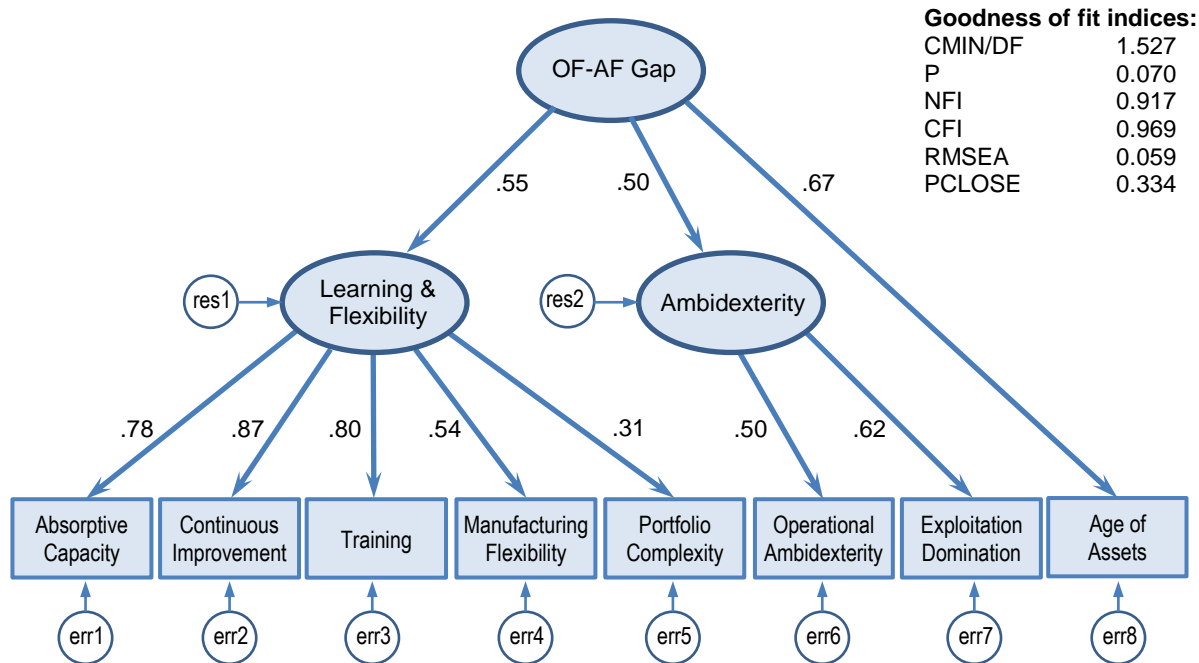


Figure 40 – Confirmatory Factor Analysis

The structural equation model successfully converged with goodness of fit indices satisfying the criteria for a 'good' fit presented in table 88. Regression values for the observable variables loading onto the latent variables are similar to the factor loadings arising from the exploratory factor analysis in table 84 – this adds further support for the developed factor structure.

A further confirmatory check undertaken was to review the correlations between the eight constituent items of the OF-AF Gap variable and the composite OF-AF Gap variable itself. A numerical value for the composite OF-AF Gap variable (appropriately weighted) can be calculated in SPSS by adding together the three factor scores that are created automatically as part of the exploratory factor analysis process [227, p705].

Table 89 presents the bivariate correlations between the eight OF-AF Gap items and the composite OF-AF GAP variable.

<b>Bivariate Correlations</b>		OF-AF Gap
Age of Assets	Pearson Correlation	.710**
	Sig. (2-tailed)	.000
Training	Pearson Correlation	.594**
	Sig. (2-tailed)	.000
Continuous Improvement	Pearson Correlation	.637**
	Sig. (2-tailed)	.000
Manufacturing Flexibility	Pearson Correlation	.412**
	Sig. (2-tailed)	.000
Product Portfolio Complexity	Pearson Correlation	.220**
	Sig. (2-tailed)	.008
Operational Absorptive Capacity	Pearson Correlation	.659**
	Sig. (2-tailed)	.000
Exploitation Domination	Pearson Correlation	.396**
	Sig. (2-tailed)	.000
Operational Ambidexterity	Pearson Correlation	.679**
	Sig. (2-tailed)	.000

\*\* Correlation is significant at the 0.01 level (2-tailed).

**Table 89 – OF-AF Gap Item Correlations**

All eight correlations are significant at the 0.01 level and have the same polarity. This provides additional support for individual items' contribution and alignment with the factored OF-AF Gap construct.

A final confirmatory check is to look at the bivariate correlations between the new OF-AF gap variable and the other major variables of this research – effectively assessing some of the correlation hypotheses of section 3.2.2.1. This will contribute to establishing criterion validity for the construct (see also section 4.3.6.1).

<b>Bivariate Correlations</b>		OF-AF GAP	Hypothesis
Innovation Propensity	Pearson Correlation	.664**	H4
	Sig. (2-tailed)	.000	
Emergent Strategy Bias	Pearson Correlation	-.433**	H5
	Sig. (2-tailed)	.000	
Firm Performance	Pearson Correlation	.270**	H7
	Sig. (2-tailed)	.001	

\*\* Correlation is significant at the 0.01 level (2-tailed).

**Table 90 – OF-AF Gap Scale Correlations**

The correlations of table 90 support the relevant hypotheses (and are significant to the 0.01 level) thereby creating criterion validity for the construct. There will be further discussion regarding correlation hypothesis confirmation in section 8.4.

### 8.3.4 Scale Validity

The criteria for successful creation and characterisation of the OF-AF Gap construct, which is a new construct to the literature, was set out in section 4.3.6.1. Table 91 reiterates those criteria and summarises the evidence that these have been satisfied.

<b>Section 4.3.6.1:</b> <i>A reliable and valid OF-AF Gap measure will be considered to have been created if the following criteria are satisfied:</i>		<b>Evidence that criteria have been satisfied</b>
<i>Items selected to form the OF-AF gap construct are appropriately justified in the literature and cover the domain of the construct.</i>		The domain of the construct was determined in section 5.2.1 and items were selected in section 5.2.2 that covered this domain. One item ( <i>Asset Utilisation</i> ) has been removed from the construct during the analysis, however the <i>Age of Assets</i> item remains to cover the structural factors group (see section 5.2.2.1).
<i>Item scales are derived from peer-reviewed literature and are unidimensional.</i>		Item scales were created in section 5.2.3 and were drawn from peer-reviewed literature sources. Unidimensionality of the question sets in their original setting was generally confirmed in section 5.4.
<i>Survey responses to individual item scales have an internal reliability (Cronbach alpha &gt; 0.7) reflecting consistency with their previous use.</i>		Survey responses to individual item scales were reviewed in section 8.2 revealing coefficients of reliability above 0.7 with the exception of Product Portfolio Complexity which was slightly lower at 0.65.
<i>Internal consistency evidenced by:</i>	<i>A stable factor structure (not sensitive to EFA method applied)</i>	Exploratory Factor Analysis in section 8.3.1 showed identical factor structures and very similar factor loadings for multiple extraction and rotation methods.
	<i>A factor structure that conceptually aligns with the literature</i>	Section 8.3.2 described the items grouped within the three factors. Factor groupings contain related items and are simply described.
	<i>A factor structure that is validated by CFA</i>	Section 8.3.3 presented the structural equation model that confirmed the factor structure arising from the EFA. Goodness of fit indices revealed a good model fit with latent variable regressions similar to EFA factor loadings.
	<i>Item scales adequately correlate with the overall construct score</i>	Table 89 showed that all individual items correlate with the overall construct score with significance at the 0.01 level.
<i>Criterion validity is established by appropriate correlation and regressions of the OF-AF gap measure with other model variables (i.e. hypotheses confirmation)</i>		Table 90 showed that correlations between the OF-AF Gap construct score and other main model variables are consistent with the literature and the hypotheses of section 3.2.2.1.

Table 91 – OF-AF Gap Scale Validity

The evidence presented in table 91 confirms that this research has successfully developed and validated a new metric to the literature – the gap between the operating and asset frontiers of manufacturing businesses. This fulfils the first objective of this research, originally proposed in section 3.2.1.

## 8.4 Main Model Correlations

Having established the OF-AF Gap metric, the research hypotheses proposed in section 3.2.2 can be evaluated. This section evaluates the *correlation* hypotheses of section 3.2.2.1 and figure 20.

Bivariate correlations between the five main model variables – Environmental Turbulence, Innovation Propensity, Emergent Strategy Bias, Firm Performance and the OF-AF Gap size – were assessed and the results are shown in table 92. The combined factor score for the OF-AF gap that was described in section 8.3.3 was used to represent this variable.

		Environmental Turbulence	Innovation Propensity	Emergent Strategy Bias	Firm Performance	OF-AF Gap
Environmental Turbulence	Pearson Correlation	1	.585** [.479, .691]	-.192* [-.406, -.012]	.234** [.026, .395]	.498** [.358, .619]
	Sig. (2-tailed)		.000	.016	.003	.000
	N	158	157	158	157	143
Innovation Propensity	Pearson Correlation	.585**	1	-.553** [-.683, -.399]	.383** [.169, .508]	.664** [.555, .760]
	Sig. (2-tailed)	.000		.000	.000	.000
	N	157	157	157	156	143
Emergent Strategy Bias	Pearson Correlation	-.192*	-.553**	1	-.259** [-.401, -.063]	-.433** [-.567, -.282]
	Sig. (2-tailed)	.016	.000		.001	.000
	N	158	157	158	157	143
Firm Performance	Pearson Correlation	.234**	.383**	-.259**	1	.270** [.101, .429]
	Sig. (2-tailed)	.003	.000	.001		.001
	N	157	156	157	157	143
OF-AF Gap	Pearson Correlation	.498**	.664**	-.433**	.270**	1
	Sig. (2-tailed)	.000	.000	.000	.001	
	N	143	143	143	143	143

\*\* . Correlation is significant at the 0.01 level (2-tailed).

\* . Correlation is significant at the 0.05 level (2-tailed).

BCa bootstrap 95% confidence intervals are reported in brackets, based on 1000 samples

**Table 92 – Main Model Bivariate Correlations**

All correlations are significant at the 0.01 level except between environmental turbulence and emergent strategy bias which is significant to the 0.05 level. Bootstrap confidence intervals mitigate against any non-normality in the sample distribution and do not straddle zero providing support for correlation polarities [227, p199 & p275].

The correlations from table 92 are added to the hypothesis model of figure 20 which results in figure 41.

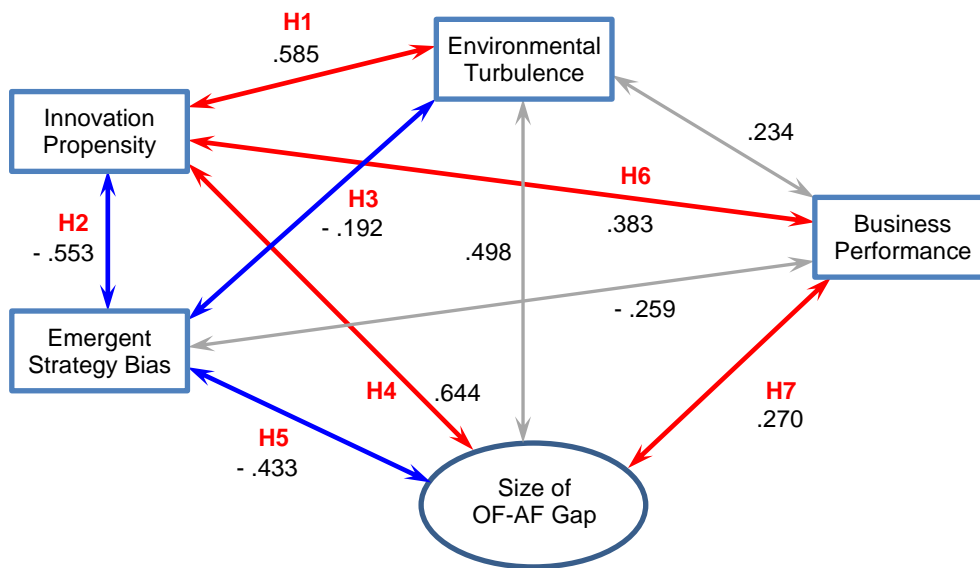


Figure 41 – Correlation Hypothesis Model

The seven correlation hypotheses of section 3.2.2.1 are reproduced in table 93 alongside the correlation results of table 92.

H	Hypothesis	Correlation	Hypothesis Supported?
1	Firms in turbulent environments have higher levels of innovation propensity	.585	Yes
2	Firms with higher levels of innovation propensity develop strategy with lower levels of emergent strategy bias.	-.553	Yes
3	Firms in turbulent environments have higher levels of emergent strategy bias.	-.192	No
4	Firms with a greater innovative propensity have a larger OF-AF gap.	.644	Yes
5	Firms with high levels of emergent strategy bias have smaller OF-AF gaps.	-.433	Yes
6	Greater innovative propensity positively correlates with firm performance.	.383	Yes
7	A larger OF-AF gap positively correlates with firm performance.	.270	Yes

Table 93 – Correlation Hypothesis Summary

Six of the seven hypotheses are supported by the research. However, hypothesis 3 is *not* supported. The correlation between environmental turbulence and emergent strategy bias is the weakest of the correlations between the five main model variables



in table 92, is the only correlation not significant at the 0.01 level, and the polarity is contrary to that hypothesised. The results suggest that in turbulent environments firms' strategic planning actually becomes more deliberate in nature rather than emergent – although this correlation is quite weak. This will be discussed further in chapter 9.

For completeness figure 41 includes the three correlations from table 92 that were not considered as part of the suite of hypotheses in section 3.2.2.1.

There is a weak positive correlation between environmental turbulence and firm performance (.234), and a weak negative correlation between emergent strategy bias and firm performance (-.259). There is however a relatively strong positive correlation between environmental turbulence and the size of the OF-AF gap (.498).

## 8.5 Main Model Causality

This section evaluates the *causality* hypotheses of section 3.2.2.2 and figure 21. This is achieved by extending the structural equation model for the OF-AF Gap variable (i.e. figure 40) to include the four other main model variables – Environmental Turbulence, Innovation Propensity, Emergent Strategy Bias and Firm Performance. In contrast to SPSS's factor analytic model, AMOS's full latent structural equation model allows the researcher to propose and model the regression structure between the latent variables and thereby test causality hypotheses [233, pp6-7].

Structural equation modelling is primarily *confirmatory* in nature. Researchers construct models by predicting relationships between observable and latent variables and then confirming the resultant model by assessing appropriate goodness of fit indices that are delivered by the analysis in AMOS. However, Byrne allows that if initial models proposed by researchers do not fit as well as is statistically recommended then a degree of exploratory model adaptation is often used to refine – or re-specify – elements of the model [233, p89 & p111]. As will be seen a degree of this *exploratory mode* of structural equation modelling has been used to achieve a good model fit.

Figure 42 shows the initial full structural equation model. The factor structure of the OF-AF Gap construct has been replicated from figure 40 (the horizontal position of the three factors has been altered for clarity of presentation). Regression arrows between the main model variables follow the causality hypothesis model of figure 21 in section 3.2.2.2. with the addition of several connections where significant *correlations* have been found.

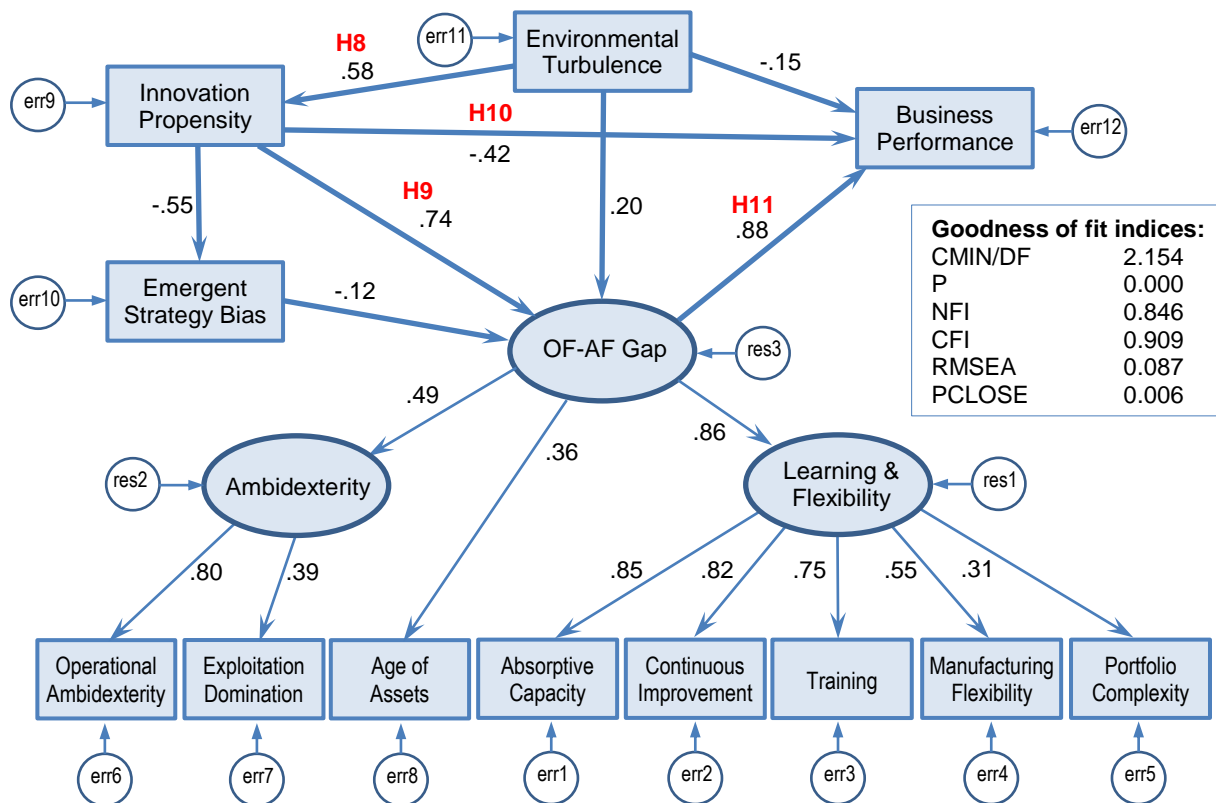


Figure 42 – Full SEM – Initial

The initial model converged satisfactorily, however the selected goodness of fit indices (as recommended by Byrne [233, p107] – see table 88) are not quite in the acceptable range. The AMOS analysis generates *modification indices* for the error covariances between observable variables. A high modification index for a pair of variables suggests there is a covariance between these variables which by default AMOS treats as strictly independent. If the covariance between the items can be supported by the theoretical origins of the model then the link between the variables can legitimately be made in the model [233, p108]. In the initial model of figure 42 there were four pairs of variables with high modification indices. These were:

- err7 – err8      Exploitation Domination – Age of Assets
- err8 – err5      Age of Assets – Portfolio Complexity
- err1 – err5      Absorptive capacity – Portfolio Complexity
- err2 – err3      Continuous Improvement - Training

Covariances between these pairs of variables can be supported by the underpinning theory. If the firm’s suite of assets are relatively new it is likely that there has been insufficient time for the business to fully exploit their capabilities [210]. Similarly a

complex product portfolio is likely to influence the investment in assets in order to maintain the flexibility required to satisfy customer orders [7]. The ability to develop complex product portfolios will relate to the level of operational absorptive capacity that firm possesses and the relative balance between *potential* and *realised* absorptive capacity. Finally, there is a clear parallel between the level of continuous improvement in a business and its attitude to learning, development and training. It is therefore legitimate to add these covariance relationships into the model.

A further re-specification of the model has been introduced at this stage as a result of exploratory development of the model. A bi-directional relationship between innovation propensity and emergent strategy bias was observed to improve the model fit. It is clear that both the innovation propensity and the emergent strategy bias of the business are attitudinal characteristics of the same group of individuals – the senior management team. It is therefore not unreasonable to observe that these characteristics influence each other.

The four covariance relationships and the bi-directional relationship between innovation propensity and emergent strategy bias have been added to the model in figure 43.

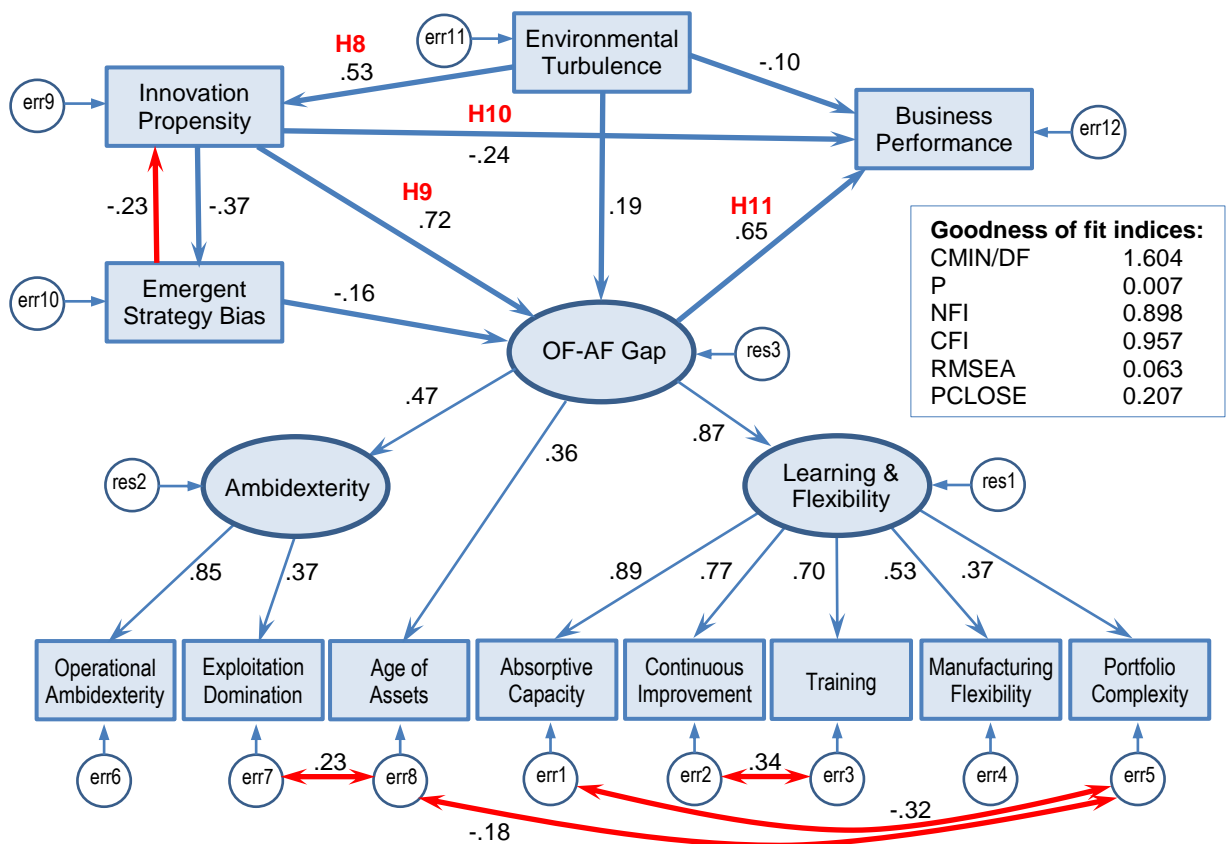


Figure 43 – Full SEM – Intermediate

The goodness of fit indices for the intermediate model in figure 43 are improved from those in the initial model of figure 42. CMIN/DF is now below 2, NFI and CFI have risen to the threshold levels of acceptability – 0.9 and 0.95 respectively – and RMSEA has reduced to 0.063, comfortably in the acceptable range.

There are two further covariances that can be considered for inclusion in the model based on the analysis of the modification indices of the intermediate model of figure 43. These are:

err6 – err10    Operational Ambidexterity – Emergent Strategy Bias

err5 – err12    Portfolio Complexity – Business Performance

Again, it is important not to represent these covariances in the model if they cannot be supported by the underlying theory. It is reasonable to observe that a high level of emergent strategy bias would potentially be related to lower operational ambidexterity as the firm focuses on short-term exploitative activity at the expense of exploration [13]. Similarly a highly complex product portfolio could lead to inferior business performance. The two covariances have been included in the final model of figure 44.

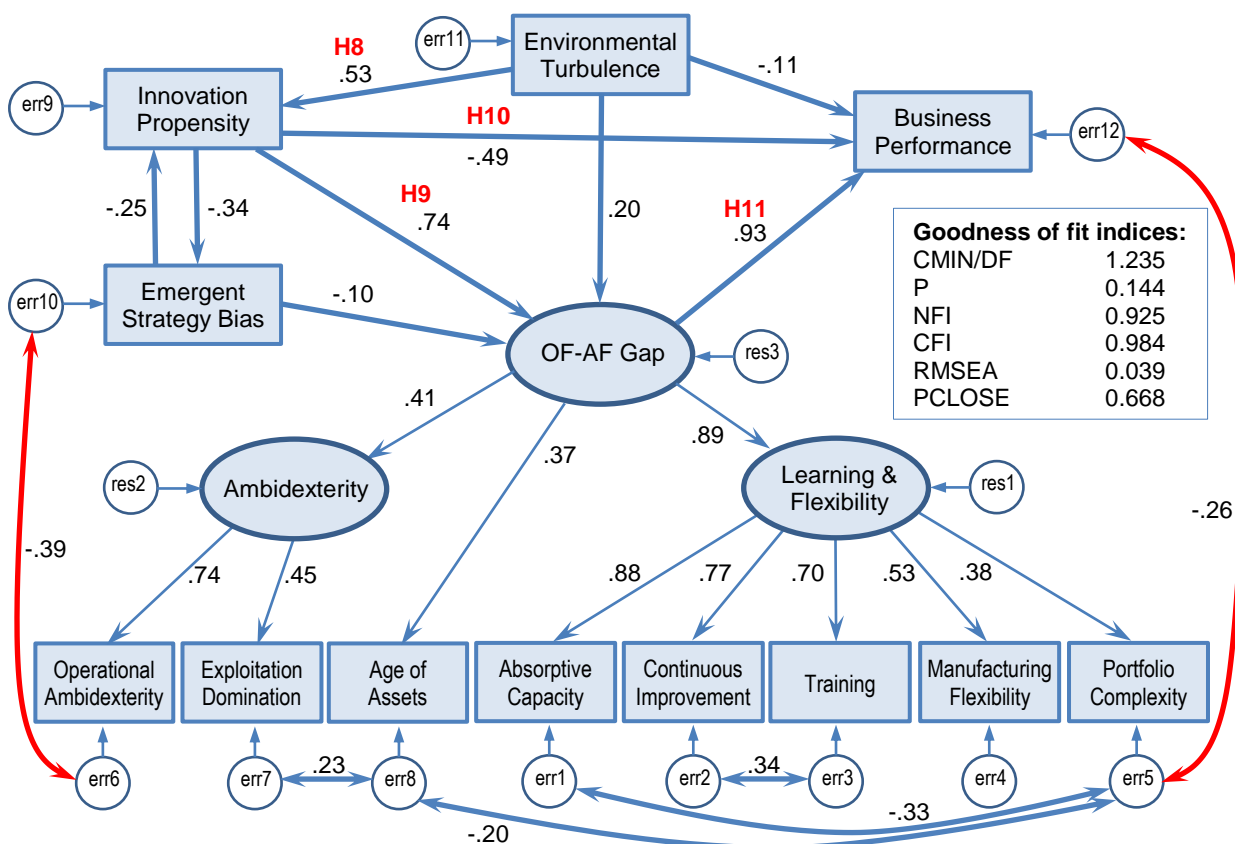


Figure 44 – Full SEM – Final

The goodness of fit indices improve further in the final structural equation model of figure 44 to the point where all six indices show a very good fit of the data to the model.

CMIN/DF	1.235	Recommended to be < 2
P	0.144	Recommended to be > 0.05
NFI	0.925	Recommended to be > 0.9
CFI	0.984	Recommended to be > 0.95
RMSEA	0.039	Recommended to be < 0.08
PCLOSE	0.668	Recommended to be > 0.5

The addition of the final two covariances takes the goodness of fit from ‘good’ in figure 43 to ‘very good’ in figure 44. Their effect on the fundamental structure of the model, the factor structure of the OF-AF gap, and the regression weights between variables can be seen to be minor. In other words, their inclusion or omission does not fundamentally impact the evaluation of the causality hypotheses.

A final confirmatory check of the robustness of the models in figures 43 and 44 can be found in Appendix C. In the appendix the four parcelled observable variables – Environmental Turbulence, Innovation Propensity, Emergent Strategy Bias and Firm Performance – are replaced with full latent variables that are defined by observable variables for each individual question in the survey (11, 9, 5 and 5 observable variables respectively). Results arising from this un-parcelling of the main model variables confirm that the simplification introduced by the parcelling in this chapter’s analysis has not compromised the conclusions that have been drawn.

The four causality hypotheses of section 3.2.2.2 are reproduced in table 94 alongside the regression results of figure 44.

H	Hypothesis	Regression	Hypothesis Supported?
8	Turbulent environments cause firms to have higher levels of innovation propensity	.53	Yes
9	A firm’s innovation propensity causes them to have a larger OF-AF gap.	.74	Yes
10	A firm’s innovation propensity causes better firm performance.	-.49	No
11	A larger OF-AF gap causes better firm performance.	.93	Yes

**Table 94 – Causality Hypothesis Summary**

Three of the four hypotheses are supported by the research. However, hypothesis 10 is *not* supported. The model suggests that higher levels of innovation propensity actually

lead to worse firm performance. This is a somewhat surprising conclusion given the positive *correlation* between innovation propensity and firm performance reported in section 8.4. This will be discussed further in chapter 9.

## 8.6 Chapter Summary

This chapter has presented the analysis of the main survey responses. Sections 8.1 and 8.2 described essential pre-checks of the data – normality and reliability. The survey sample size allows the central limit theorem to take effect thereby removing the absolute need for normality of data outcomes, however the analysis shows that there is high level of normality, particularly when considered at the industry categorical level. Scale reliability checks for the OF-AF gap variables and main model variables predominantly show coefficients of reliability greater than 0.7 with item correlations greater than 0.3. This reinforces the results of the source literature and provides confidence in the unidimensionality of each variable.

Section 8.3 presented the exploratory and confirmatory factor analysis of the nine items making up the OF-AF gap construct. During this process one item was excluded from the analysis – *Asset Utilisation* – having been revealed as an unreliable component. The remaining eight items were shown to load onto the OF-AF gap latent variable in three distinct factors – *Learning & Flexibility*, *Ambidexterity* and *Age of Assets*. The correlations between the eight individual items and the composite OF-AF gap variable, and correlations between this composite variable and other main model variables were checked. Evidence that the criteria set out in section 4.3.6.1 for the successful creation of the new OF-AF gap measure have been met was summarised in table 91, thereby satisfying the first objective of this research originally proposed in section 3.2.1.

Section 8.4 examined the correlations between the new OF-AF gap measure and the other main model variables. The correlation hypotheses of section 3.2.2.1 were thus tested and there was support for six of the seven hypotheses.

Section 8.5 extended the structural equation model used for the confirmatory factor analysis to include the other main model variables. This full latent model was used to test the causality hypotheses of section 3.2.2.2 and three of the four hypotheses were supported.

Chapter 9 will discuss the results of the analysis in more detail.

## Chapter 9: Discussion

This chapter considers the results of the statistical analysis presented in chapter 8 in the context of the literature landscape described in chapter 2 and the hypothesis development of chapter 3. Section 9.1 reviews the characterisation and validation of the OF-AF gap measure and section 9.2 discusses the testing of the correlation and causality hypotheses. Section 9.3 considers the effect sizes arising from the analysis, section 9.4 the generalisability of the results to the wider manufacturing population. Finally the chapter is summarised in section 9.5.

### 9.1 OF-AF Gap Measure

Schmenner & Swink's Theory of Performance Frontiers [1] was introduced in the literature review in section 2.3.7. This theory purports to explain how both capability trade-offs and cumulative capability building can co-exist in the same organisation with the degree each manifests themselves depending on the 'distance' between the operating and asset frontiers. Several authors build on this basic premise [7, 203, 204, 209, 210] extending the theoretical arguments, but there is very limited practical application of the theory. The only examples appear to be Lapre & Scudder [205] and Ramdas & Williams [206] who implement the theory in the airline industry, but their approach is not generally applicable to the wider population of manufacturing businesses.

The theoretical arguments presented in section 3.1 contend that the higher-order operational capabilities of flexibility and agility are a key component of the ability to orchestrate resources in the pursuit of realising the innovative ambition of the firm. Performance frontier theory posits that these catalysts for responsive innovation – flexibility and agility – are more likely to be present if there is a greater 'distance' between the operating and asset frontiers.

The first objective of this research was therefore to measure this gap between operating and asset frontiers in a manner that could be generally applicable to manufacturing companies. A strictly objective, numerical evaluation was not feasible because of the different dimensions of two frontiers [209, p132], and therefore a reflective item scale has been developed which is appropriate for such a latent and continuous variable [223].

The construction and validation of the OF-AF Gap scale in this research has closely followed guidance in the literature [215, 223-227] and the criteria for its successful creation set out in section 4.3.6.1. The domain of the construct based on the literature was defined in section 5.2.1, and nine content-valid items covering this domain were selected in section 5.2.2. The third stage of the process, measure purification, was conducted by analysing and refining the factor structure of the measure using a combination of exploratory and confirmatory factor analysis in sections 8.3.1 and 8.3.2.

The early stages of the exploratory factor analysis revealed that one of the nine items was problematic. *Asset Utilisation* had a very low item correlation in the initial reliability analysis (table 76), had low correlations with the other eight items (table 77), and the anti-image correlation matrix suggested poor sampling adequacy (table 78). The *Asset Utilisation* item was therefore excluded from the subsequent analysis in chapter 8. This exclusion was justifiable in strictly numerical terms according to general factor analysis guidance [227]. To further test the validity of excluding *Asset Utilisation* the author persisted with the item through the factor extraction and confirmatory factor analysis processes in spite of the statistics guidance. For clarity and brevity this work was not reported in chapter 8. The factor extraction process was found to be unstable, with different factor structures and loadings emerging when different extraction methods and matrix rotation combinations were employed. Subsequent structural equation models based on these factor analyses did not converge suggesting model misspecification. This additional evidence confirmed the validity of the decision to exclude the *Asset Utilisation* item from the development of the OF-AF gap scale.

Having excluded an item from the scale development process it is reasonable to speculate as to why this might have been necessary and whether the domain of the OF-AF gap construct continues to be adequately represented by the remaining eight items.

Section 5.2.2.1 described the rationale for the inclusion of asset utilisation as an item to cover the structural (or tangible) factors associated with the OF-AF gap domain. A measure to assess the difference between the manufacturing capacity at the operating frontier and the manufacturing capacity at the asset frontier was defined as an indicator of the OF-AF gap. The peer-reviewed survey mechanism selected to elicit this measure was described in section 5.2.3.1. Fundamentally, this asked the respondent to estimate '*how much it is currently practicable to increase production without raising unit costs*'.

In retrospect there are a number of issues with this survey question. Firstly, and perhaps most importantly, it assumes that the respondent's company is currently



functioning at the operating frontier. That is, it has removed all the inefficiencies in its existing processes (see also figure 16). The relatively simple survey question employed does not make this clear, and indeed even if the distinction had been explicitly made most respondents would find it difficult to evaluate without being familiar with the theoretical background. It is therefore very probable that respondents have been inadvertently inconsistent in their interpretation of this question. Respondents are likely to have reported the ability to increase capacity due to not only the distance between their operating and asset frontiers, but also due to the distance between their actual operating position and their operating frontier.

There are also issues with the format of the question response. Respondents are asked to indicate their firm's capacity (under)utilisation by selecting one of five ranges. This results in a non-linear ordinal data set for this variable. This is the only variable with this data type. It may be that treating this variable's data as effectively scalar in the multiple correlation analyses in chapter 8 masks any underlying validity of the responses.

A recommendation for further research in chapter 12 will be to re-assess how an item scale representing asset utilisation, explicitly capturing responses strictly according to the definition in section 5.2.2.1, can be created that at the same time delivers scalar data. If this can be achieved then it can be established whether asset utilisation is in fact a component part of the OF-AF gap construct and that its failure in this research is due to the measurement mechanism, or whether it is actually *not* a constituent element of the OF-AF gap as this research concludes.

Having excluded one variable, adequate coverage of the domain of the OF-AF gap construct must be considered. *Asset Utilisation* and *Age of Assets* were selected in section 5.2.2.1 to represent structural and tangible factors of the domain. Structural factors include facilities, technology, capacity and investment [1, 7, 209, 239]. Although *Asset Utilisation* sought to capture the capacity element of this group, *Age of Assets* in fact successfully addresses all four to a greater or lesser extent. The investment in a firm's facilities, the maturity of manufacturing technology employed, and the ultimate production capacity made available by its assets can be seen to be correlated to the age of those assets. Age of Assets therefore adequately represents the structural factors of the OF-AF gap measure.

Exploratory factor analysis using the remaining eight items revealed a stable factor structure that was subsequently confirmed using a well-fitting structural equation model. The OF-AF gap construct is found to consist of three factors.

The first of these, which has been labelled **Learning & Flexibility**, comprises five of the eight items:

- Operational Absorptive Capacity (0.89)
- Continuous Improvement (0.77)
- Training (0.70)
- Manufacturing Flexibility (0.53)
- Product Portfolio Complexity (0.37)

Regression values from the intermediate structural equation model of figure 43 in section 8.5 are shown above in parentheses to indicate the relative contribution of each of the five items.

The case for including operational absorptive capacity, which has the greatest contribution to the Learning & Flexibility factor, was presented in section 5.2.2.3. Extending the asset frontier out in front of the operating frontier requires firms to have adequate levels of both potential and realised absorptive capacity in order that they can understand, assimilate and apply new outside knowledge that is associated with new investments [195, p204].

Continuous improvement and training, which have similarly high contributions to the Learning & Flexibility factor, were originally included in the OF-AF gap scale item list in section 5.2.2.2. These two drivers of capability development enhance firm performance by both bettering the operating frontier and, when coupled with asset investments, by extending the asset frontier. Rosenzweig & Easton [242] contend that:

*“... the existence of substantive performance-enhancing initiatives would contradict the assumption that the manufacturer is close to the asset frontier...” [242, p131]*

It is clear that there is a common thread of organisational learning running through these first three elements, but they are distinct facets of this broad topic. This distinctness was confirmed by the exploratory and confirmatory factor analysis process. The factors were shown not to have high levels of multicollinearity (section 8.3.1) and not to have significant covariances (section 8.3.3). Each element brings a different emphasis to this learning factor. Absorptive capacity emphasises the ability to understand and assimilate new knowledge, continuous improvement focuses on the implementation, or consequence, of that new knowledge, while training is a more general indicator of individual and organisational learning.

Manufacturing Flexibility and Product Portfolio Complexity were included as potential indicators of the size of the OF-AF gap in section 5.2.2.4. Although they contribute least to the Learning & Flexibility factor, their contribution is still significant. Complex product portfolios require a greater gap between operating and asset frontiers as different product mixes place different demands on the manufacturing plant [7, p356]. The inherent flexibility required to deliver the complexity of the portfolio effectively therefore has parallels with the more general manufacturing flexibility variable that it accompanies. Flexibility is one of the 'traditional' key manufacturing capabilities that can only be realised when other more foundational capabilities are in place [190] [192] and such higher-order capabilities can only be cumulatively built if there is space between the operating and asset frontier [242, p131].

The second OF-AF gap factor revealed by the exploratory and confirmatory factor analysis, which has been labelled **Ambidexterity**, comprises two of the eight items:

- Operational Ambidexterity (0.85)
- Exploitation Domination (0.37)

Operational Ambidexterity and Exploitation Domination were included as potential indicators of the size of the OF-AF gap in section 5.2.2.3. It was shown that high levels of operational ambidexterity, that is a small difference in the quantity of explorative and exploitative activities, facilitates extension of the asset frontier through asset and technology acquisition thereby widening the OF-AF gap [248, p C3]. This is reflected in the relatively large contribution operational ambidexterity makes to the overall OF-AF gap construct. More subtle is the particular effect of the lack of domination by exploitative activities. Dominant exploitative activity closes the OF-AF gap through betterment of the operating frontier while neglecting the investment in new products and technologies required to extend the asset frontier [196, p6177]. These two variables are clearly related as they are based on different numerical combinations of the same two elements – exploitation and exploration. However they have been shown to be distinct through the exploratory and confirmatory factor analysis process. The factors were shown not to have high levels of multicollinearity (section 8.3.1) and not to have significant covariances (section 8.3.3).

A recommendation for further research in chapter 12 will be to re-assess this component of the OF-AF gap in order to clarify the mechanisms by which the nature of a firm's ambidexterity drives the size of the OF-AF gap.

The third OF-AF gap factor revealed by the exploratory and confirmatory factor analysis is **Age of Assets**. Age of Assets was included as a potential indicator of the size of the OF-AF gap in section 5.2.2.1. It was shown that as assets mature over time operating and asset frontiers tend to converge [210, p1185]. This has been strongly validated by the factor analysis revealing that this item loads directly onto the OF-AF gap variable.

The three factors, Learning & Flexibility, Ambidexterity and Age of Assets, combine to form the OF-AF gap construct. The regression values from the intermediate structural equation model of figure 43 in section 8.5 are shown below in parentheses to indicate the relative contribution of each of the three factors.

- Learning & Flexibility (0.87)
- Ambidexterity (0.47)
- Age of Assets (0.36)

The final stage of the scale development process, to establish the new scale's reliability and validity, is itself comprised of several elements. *Internal consistency* and *criterion-related validity* were established using objective measures reported in section 8.3.3. *Construct validity* is perhaps the most difficult to establish because it requires the researcher to demonstrate that the new scale actually measures the unobservable variable it is designed to.

Section 4.3.6.1 presents several authors' contentions as to how construct validity can be built up and these include robust and stable exploratory and confirmatory factor analysis and evidence that the measure behaves with other independent measures in accordance with the literature [217, 225, 235]. These elements were incorporated in the benchmark criteria necessary to claim successful creation of the OF-AF gap metric in section 4.3.6.1, and evidence that those criteria had been satisfied was summarised in table 91 in section 8.3.4.

Additionally, it will be seen in the next chapter, chapter 10, that selected categorical means of a firm's OF-AF gap score, directly calculated from survey responses, also behave in accordance with the literature and the hypotheses of this research.

Notwithstanding this cumulative evidence of the construct validity of this new measure, it would be desirable to be able compare it to other metrics designed to measure the

same thing. This is often the primary test for a new metric to the literature [224, p70]. However this is not possible when the underlying construct has not been measured before, as is the case here. This dilemma is behind Schriesheim's contention:

*'... it may be an unrealistic pre-publication requirement to demand a full-scale attack on the construct validity of a new, previously untested ... measure'* [234, p389]

A recommendation for further research in chapter 12 will therefore be for other researchers to seek refinements of this research's approach to measure the OF-AF gap to enable its construct validity to be enhanced.

## 9.2 Hypotheses Testing

Having established a measure representing the distance between a manufacturing organisation's operating and asset frontiers, the second objective of this research is to evaluate the relationship between the size of the OF-AF gap and the other main model variables. As such the contentions originally presented in section 3.2.2 comprise both correlation and causality hypotheses.

Figure 45 summarises both the correlations between model variables from figure 41 in section 8.4 and the regressions between model variables from the final structural equation model of figure 44 in section 8.5. Hypothesis references from sections 3.2.2.1 and 3.2.2.2 are prefixed by the letter 'H' (e.g. H1, H2, etc).

**Hypothesis 1** contended that firms in turbulent environments have higher levels of innovation propensity and **Hypothesis 8** went further to contend that turbulent environments *cause* senior management teams to have higher levels of innovation propensity. Strong support for both of these hypotheses has been found in the analysis, suggesting businesses recognise the threat turbulence brings, and more specifically the potential for technological discontinuities, and in this context senior management teams adopt an innovative posture in line with guidance for this type of environment (e.g. Bessant & Francis [22] and Phillips et al [23]).

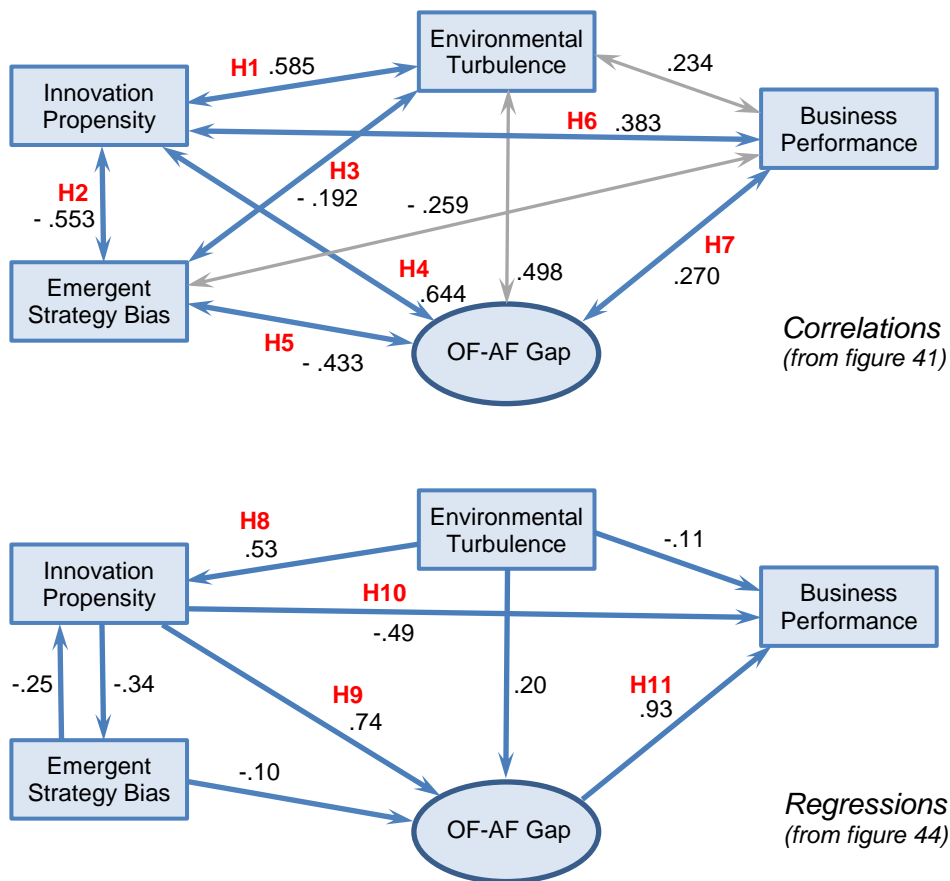


Figure 45 – Hypothesis Summary

**Hypothesis 2** suggested that firms that have a propensity to innovate are more aware of their environment, take a longer term perspective and are better prepared, which leads them to develop their business strategy more deliberately, with less need to respond to events in a reactive manner [18]. This has found support in the analysis with a strong negative correlation between innovation propensity and emergent strategy bias. The structural equation model reveals an interesting dynamic in the regressions between innovation propensity and emergent strategy bias. There appears to be a degree of bi-directional causality between these variables. This is perhaps not surprising as both reflect attitudinal characteristics of the senior management team. It suggests a self-reinforcing cycle of influence where increased innovation propensity drives longer-term market and technological planning making the firm better prepared and more agile to respond to events as they emerge. This increased preparedness reduces the need to develop strategy emergently. Correspondingly, an emphasis on deliberate planning extending to the periphery of the technological horizon will reveal opportunities for innovation that perhaps would otherwise be hidden from view [94] [95], encouraging and reinforcing the propensity to innovate.

**Hypothesis 3** posited that firms in turbulent environments have higher levels of emergent strategy bias. Christensen [13] and Quinn [96] suggest that strategy development becomes more emergent in nature in turbulent environments as firms succumb to the tendency to adapt strategy to new information as it comes to light. The hypothesis is *not* supported by the outcome of this research. The correlation between these two variables is actually weakly negative, and is significant only at the 0.05 level whereas all the other correlations were significant at the 0.01 level. It suggests that in turbulent environments organisations' strategy development processes become more *deliberate* in nature. This result could be reflecting Stieglitz et al's observation that constantly shifting technological landscapes can lead to some organisations actually becoming more inert as they recognise the danger of regularly changing strategic direction in response to external stimuli only to find once a strategy change has been executed the external environment has changed yet again [213, p1855]. However the weakness of the correlation arising from this research leads this author to draw no conclusion about the relationship between the two variables beyond the fact that the hypothesis is not supported by the research.

Reconfiguring and acquiring new resources to effect changes to the relative positions of the operating and asset frontiers requires deliberate strategic actions and this is at the heart of **Hypothesis 5**, which contended that firms with a higher level of emergent strategy bias have a correspondingly small OF-AF gap. This hypothesis finds support in the analysis with a strong negative correlation between the two variables. The structural equation model results show that in spite of this strong correlation there is no direct regression of any significance (only -0.1 ) between the two variables. This suggests that the effect that the relative proportion of deliberate and emergent strategy development has on the size of the OF-AF gap is mediated by the innovation propensity of the senior management team.

Three correlations that were not part of the suite of correlation hypotheses in section 3.2.2.1 are shown in figure 45 for completeness. All are significant at the 0.01 level and are between Environmental Turbulence and Business Performance (0.234), Environmental Turbulence and the OF-AF Gap (0.498), and Emergent Strategy Bias and Business Performance (– 0.259). Interestingly, the regressions between these variables in the structural equation model were relatively much less significant, respectively: -0.11, 0.20, and less than 0.1 (not shown in figure 45). The evident significant correlations between these variables therefore do not contribute to the explanation of the underlying dynamics of this system of variables.

For clarity, figure 46 extracts the correlations and regressions from figure 45 relating to the primary OF-AF gap relationships.

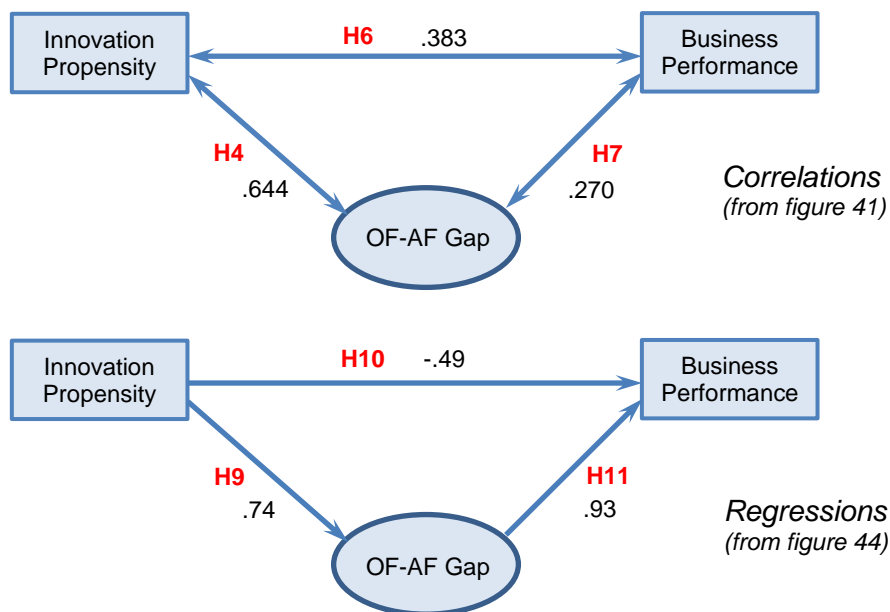


Figure 46 – Primary OF-AF Gap Relationships

**Hypothesis 4** posited that organisations with a propensity for innovation will extend the asset frontier out in front of the operating frontier in order to create the space to realise their innovative efforts, and that therefore there is a correlation between innovation propensity and the size of the OF-AF gap. **Hypothesis 9** went further to contend that a senior management team’s innovation propensity will *cause* the business to develop a larger OF-AF gap. Both of the hypotheses are strongly supported by the analysis, with a significant positive correlation and regression.

The relationship between innovation propensity and business performance, and the effect the size of the OF-AF gap has on it, revealed the most significant, and somewhat surprising, result of this research. **Hypothesis 6** contended that there should be a positive correlation between a firm’s innovation propensity and its performance. Given the weight of literature evidence supporting this straightforward contention (for example Buisson & Silberzahn [3], Dobni [62] and Tidd & Bessant [4], to name just three) it was not surprising to see strong support for this hypothesis. Indeed, Dobni states:

*“What is clear is that innovative firms are more successful over the long term. They have a unique anatomy in that they are more creative, have a desire to succeed, possess a common sense of purpose and constituency,*



*and are empowered. They understand the relationship between strategy and innovation, and they have identified the configurations that are best suited to their environment. This positioning allows them to constantly realign with changes in the competitive context.” [62, p336]*

The result of evaluating **Hypothesis 10** however, brings Dobni’s assertion above into sharp relief. Hypothesis 10 simply extended hypothesis 6 by suggesting that the correlation between innovation propensity and business performance is simply mirrored by a corresponding positive regression – innovation propensity directly causes better firm performance. This research suggests that this is not the case. The strong negative regression indicates that innovation propensity is, in fact, a *counterproductive* characteristic of the business *unless* it is mediated by the gap between the operating and asset frontiers.

This conclusion is supported by an argument that suggests that unfulfilled innovative ambition can be a significant distraction to the business. A propensity to innovate in isolation, or when manifesting itself in numerous uncoordinated explorative activities is likely to have an adverse effect on firm performance. He & Wong observe that

*“... experimenting with new alternatives reduces the speed at which existing competencies are improved and refined. A failed explorative effort may disrupt successful routines in a firm’s existing domains, without any significant success in the new field to compensate for the loss in existing business.” [244, p482]*

Similarly, Atuahene-Gima suggests that

*“Too much exploration could be costly because the firm may move from one new idea to the next without exploiting prior learning and experience. In addition, novel products may be underdeveloped, and their fit with customer needs may be unknown. A dose of exploitation tempers these potential excesses of exploration by helping the firm evaluate and assimilate new ideas more effectively.” [99, p65]*

So a firm’s enthusiasm, desire and propensity to innovate must be accompanied by structural and infrastructural factors to ensure that innovative ambition realises positive financial results. In the two examples above He & Wong and Atuahene-Gima refer to the mediating effect of ambidexterity on the financial impact of innovation propensity,

and indeed ambidexterity is one component of the OF-AF gap measure. It is not an unreasonable outcome from the analysis that the other two components of the OF-AF gap measure – Learning & Flexibility and the Age of Assets – also contribute to this mediating role.

Not only does the size of the OF-AF gap support the innovative ambition of the firm, it actually *reverses* the underlying negative effect innovative propensity in isolation has on business performance. This phenomena has consequences for the relationship between the OF-AF gap and business performance variables which is considered in hypotheses 7 and 11. The mediocre support for **Hypothesis 7** (a correlation coefficient of 0.27) is overshadowed by the highest relative regression coefficient of the structural equation model (0.93) in support of **Hypothesis 11**.

The significant mediation effect that the size of the OF-AF gap has on the relationship between innovation propensity and business performance has important implications for its three components. These will be discussed in chapter 11.

### 9.3 Effect Sizes

Section 4.3.6.6 determined the minimum sample size to be able to detect small-medium effect sizes. The ability to detect effect sizes of this magnitude was deemed appropriate prior to survey deployment and analysis. The regressions (R) returned by the analysis for the four causality hypotheses (H8 – H11) shown in figure 45 are 0.53, 0.74, -0.49 and 0.93 respectively. The corresponding effect sizes ( $R^2$ ) are 0.28, 0.55, 0.24 and 0.86 respectively. Three are greater than a 'large' effect ( $> 0.26$ ) with one just below this limit but significantly greater than a 'medium' effect ( $> 0.13$ ) [286, 287].

Therefore the actual effect sizes arising from the research were significantly greater than anticipated.

With the statistical power of the analysis ( $1-\beta$ ) set at the recommended level of 0.8 [227, p69], and with 12 predictor variables (8 OF-AF gap variables and 4 main model variables) the required sample sizes to reliably detect these effect sizes are 125 for a 'medium' effect and 60 for a 'large' effect [227, p314]. This research's sample size of 158 is greater than these levels, confirming the statistical reliability of the detected effects.

## 9.4 Generalisability

In order to generalise the conclusions drawn from the testing of the causality hypotheses to the wider population of manufacturing businesses, the effect sizes observed should be considered in the context of the sample size, the population size, confidence levels and margin of error.

Using a web-based sample size calculator tool [288] the generalisability of this research's conclusions can be enumerated. The following input data is used:

- Sample size of **158** (see section 7.4)
- Population size of **20,000** (default recommendation when the actual population is uncertain)
- Confidence level of **95%** (default recommendation)
- Response distribution of **70%** (derived from distribution of OF-AF gap scores in section 10.1.3)

The calculator tool calculates a margin of error of **7.12%** for this set of inputs. Given the predominantly large effect sizes arising from the research when compared with this margin of error it can be concluded that there is good generalisability of the research conclusions to the wider population.

## 9.5 Chapter Summary

This chapter has discussed the results arising from the statistical analysis presented in chapter 8. In section 9.1 the development of the factor structure of the OF-AF gap metric has been considered in the context of the literature review and hypothesis development of chapters 2 and 3 respectively. The factor structure is found to be logically consistent with extant theory and the propositions of this research. Several areas of further research have been identified to be brought forward to chapter 12 – Limitations & Recommendations.

Section 9.2 reviewed the support for the correlation and causality hypotheses proposed in chapter 3. The analysis revealed support for six of the seven correlation hypotheses (with an inconclusive result for the seventh) and support for three of the four causality hypotheses. The strong contradiction of hypothesis 10 found in the analysis has led to

the conclusion that the size of the OF-AF gap not only mediates the relationship between innovation propensity and business performance (as proposed in chapter 3), but it actually reverses the negative effect that innovation propensity in isolation has on business performance. This has important implications for managers that will be discussed in chapter 11.

Finally, section 9.3 reviewed the effect sizes arising from the regression analysis and section 9.4 calculated the theoretical margin of error in the wider population from the sample size employed. These sections showed that the sample size realised in this research is sufficient to achieve recommended levels of statistical power for the relatively large effect sizes observed, and that the relatively large effect sizes compare well with the predicted margin of error in the wider population. This provides support for the generalisability of the analysis to the wider population of manufacturing businesses.

The next chapter describes the development and validation of a normalised numeric scale for the OF-AF gap that can be computed directly from survey responses using a readily accessible tool such as a spreadsheet.

## Chapter 10: Numeric OF-AF Gap Scale

In chapter 8 the factor structure of the new OF-AF gap latent variable and the relative loadings of those factors was derived as the responses to the main survey were analysed. This allowed the relationship between the OF-AF gap and the other main model variables to be explored.

The numerical 'value' for each respondent's company's OF-AF gap can be calculated in SPSS by adding the three factor scores arising from the factor analysis. This composite factor score representing the OF-AF gap was used in sections 8.3.3 and 8.4 to examine correlations with its eight constituent variables.

It would be useful to be able to derive a numeric score for the OF-AF gap directly from the survey responses without the need to process them in SPSS. This would make the enumeration more accessible and allow inter-firm comparisons to be readily made. The development of a normalised, numeric scale – as suggested by Churchill [224, p72] – was proposed in section 4.3.6.1 as the final step in the process of creating a reliable, valid and *usable* metric.

Section 10.1 describes the development and validation of such a numeric scale and section 10.2 presents selected comparisons of company scores along it.

### 10.1 Numeric Scale Development

The objective is to create a single, normalised score from individual responses to the question sets of each of the eight constituent variables of the OF-AF gap. The eight variables have questions sets totalling 58 questions. Processing of the responses should only require a readily accessible tool such as a spreadsheet.

#### 10.1.1 Variable Normalisation

The first step is to create normalised scales (0 → 1) for each of the eight components of the OF-AF gap measure based on individual answers to their respective question sets. The methods used to normalise each variable are described below.

### **Age of Assets**

Respondents are asked to apportion their suite of manufacturing equipment into five age categories. The Age of Assets value is then calculated using the following formula in line with the literature source [256]:

$$(' < 2 \text{yr}' + (' 3-5 \text{yr}' \times 4) + (' 6-10 \text{yr}' \times 8) + (' 11-20 \text{yr}' \times 15.5) + (' > 20 \text{yr}' \times 25)) / 100$$

The maximum score that can be returned is 25 years and the minimum is 1 year. To ensure the correct polarity of the variable (see also sections 7.5.3 and 7.5.4) the normalised score is calculated using the formula:

$$(25 - \text{Age of Assets}) / 24$$

### **Continuous Improvement**

The five questions in this question set are based on a Likert scale with minimum score of 1 and maximum of 7. The average of the five responses is then normalised using the formula:

$$(\text{Continuous Improvement} - 1) / 6$$

### **Training**

The four questions in this question set are based on a Likert scale with minimum score of 1 and maximum of 7. The average of the five responses is then normalised using the formula:

$$(\text{Training} - 1) / 6$$

### **Manufacturing Flexibility**

The seven questions in this question set are based on a Likert scale with minimum score of 1 and maximum of 5. The average of the five responses is then normalised using the formula:

$$(\text{Manufacturing Flexibility} - 1) / 4$$

### **Product Portfolio Complexity**

This variable is based on the sum of four questions each with a score between 1 and 5. This results in a total score between 4 and 20. The normalised variable is calculated using the formula:

$$(\text{Product Portfolio Complexity} - 4) / 16$$

### **Operational Absorptive Capacity**

The responses to the nine questions relating to potential absorptive capacity (PAC) and the 12 questions relating to realised absorptive capacity (RAC) are averaged. These aggregates are then added together to create Operational Absorptive Capacity – see section 7.5.3. Question items in these question sets are based on a Likert scale with minimum score of 1 and maximum of 7. Operational Absorptive Capacity is then normalised using the formula:

$$(PAC + RAC - 2) / 12$$

### **Operational Ambidexterity**

Both Operational Ambidexterity and Exploitation Bias are based on the question sets for Exploitation and Exploration, each of which have six questions based on a Likert scale with minimum score of 1 and maximum of 5. Exploitation and Exploration question sets responses are averaged and then Operational Ambidexterity is calculated by using the *absolute* difference between Exploitation and Exploration in the formula:

$$(4 - ABS(\text{Exploitation} - \text{Exploration})) / 4$$

This ensures the correct polarity of the variable – see also sections 7.5.3 and 7.5.4.

### **Exploitation Domination**

Exploitation Domination is the degree to which Exploitation is greater than Exploration, but in order achieve the correct polarity of the variable – see sections 7.5.3 and 7.5.4 – the order of subtraction is reversed. The variable formula is therefore:

$$(\text{Exploration} - \text{Exploitation} + 4) / 8$$

Having created eight variables of the correct polarity and each with a range between 0 and 1, the next stage is to create the three factors of the OF-AF gap measure. This is presented in the next section.

## 10.1.2 Factor Creation

In order to create the OF-AF gap's constituent three factors the regression values generated by the intermediate structural equation model in figure 43 in section 8.5 have been used as variable weightings. These are almost identical to those shown in the *final* structural equation model of figure 44, and have the advantage of not being influenced by the added covariances between OF-AF gap variables and main model variables that were introduced in the final model of figure 44.

Table 95 shows the regression values from the SEM in figure 43 for the OF-AF gap variables for the first two factors.

		SEM (fig 43) Regressions
<b>Learning &amp; Flexibility Factor</b>		
Absorptive Capacity	AC	0.89
Continuous Improvement	CI	0.77
Training	TR	0.70
Manufacturing Flexibility	MF	0.53
Product Portfolio Complexity	PPC	0.37
<b>Ambidexterity Factor</b>		
Operational Ambidexterity	OA	0.85
Exploitation Domination	ED	0.37

Table 95 – Variable Regressions

The composite Learning & Flexibility factor is therefore calculated using the formula:

$$((AC*0.89) + (CI*0.77) + (TR*0.7) + (MF*0.53) + (PPC*0.37)) / 5$$

Similarly, the Ambidexterity factor is calculated using the formula:

$$((OA*0.85) + (ED*0.37)) / 2$$

The third factor – Age of Assets – remains untouched as it is composed of a single variable.

Having created a numeric value for each of the three factors, their validity can be assessed by recreating the structural equation model of figure 43 using these *calculated* variables instead of the original *latent* variables for the Learning & Flexibility and Ambidexterity factors. This is in effect *parcelling* each factor's constituent variables



into higher level observable variables. The eight variable normalisations and the construction of the Learning & Flexibility and Ambidexterity factors were computed in SPSS. The resulting AMOS SEM model is shown in figure 47.

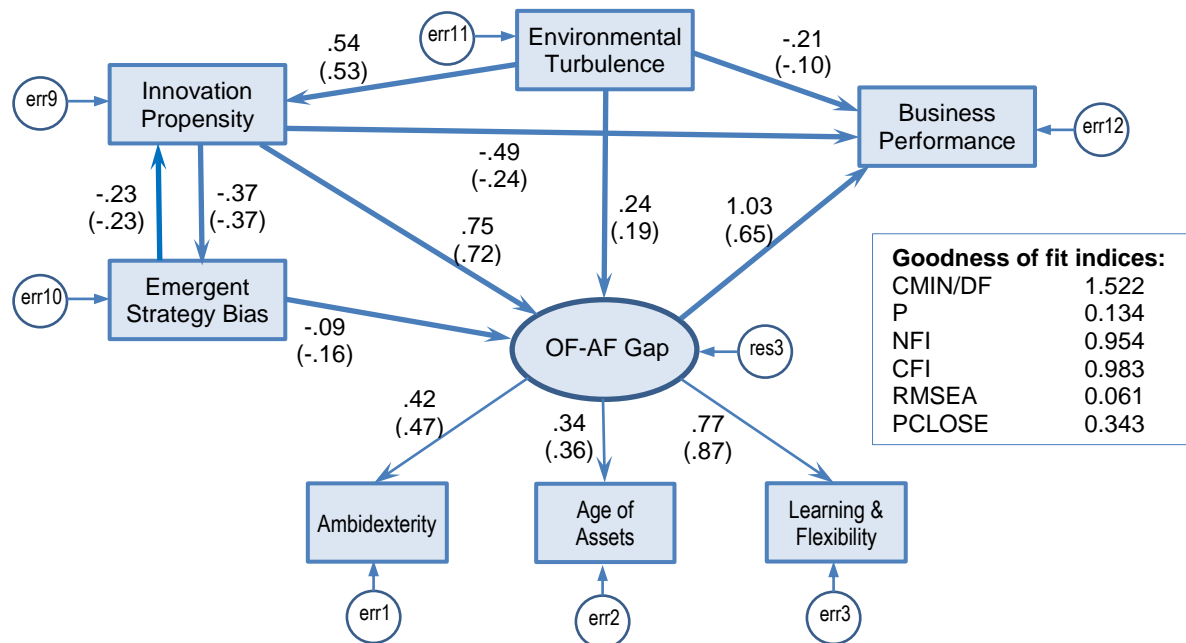


Figure 47 – SEM Using Calculated OF-AF Gap Factors

For ease of comparison the regression values from the SEM model of figure 43 are shown in parentheses. It can be seen that the regression values of the three calculated factors that load onto the OF-AF gap latent variable are very similar to the original model. The regression values in the rest of the model are also comparable to the original SEM. The goodness of fit indices also show a very good fit to the data for this model.

The similarity of the regression values of the SEM using calculated OF-AF gap factor scores shown in figure 47 to those of the original SEM model of figure 43, provides evidence that the calculated factor scores adequately approximate the statistical treatment SPSS and AMOS apply when modelling the original data.

The final step is to combine the three calculated factor scores into a single numeric variable.

### 10.1.3 Full Numeric Scale

Before combining the three factor scores into a single value, each factor was normalised again by dividing by the maximum value theoretically possible for each variable, i.e. **0.65** for Learning & Flexibility, **0.52** for Ambidexterity and **1.0** for Age of Assets. Each variable is then multiplied by the regression values for each factor found in the intermediate structural equation model in figure 43 in section 8.5, i.e. **0.87** for Learning & Flexibility, **0.47** for Ambidexterity and **0.36** for Age of Assets. The resulting formula for the OF-AF gap calculation is therefore:

$$(\text{Learning \& Flexibility} * 0.87/0.65) + (\text{Ambidexterity} * 0.47/0.52) + (\text{Age of Assets} * 0.36)$$

A final normalisation coefficient –  $(100 / (0.87+0.47+0.36))$  – is applied to set the maximum possible OF-AF gap score to 100.

The combining of the three factors into a single numeric cannot be validly tested in the structural equation model in the same way that the calculated factors were tested in figure 47. There are three problems with attempting to do this:

- As described in section 4.3.6.1, parcelling variables for use in SEM should only be applied if the items are unidimensional, otherwise accuracy and validity of results are seriously affected [230, p168]. The three factors are not unidimensional in the same way that their constituent variables are.
- The model would consist only of observable variables. The lack of latent variables means that the model could potentially generate a path analysis, but would not constitute a structural model thereby limiting the causality conclusions that could otherwise be drawn.
- The reduced number of observable variables tends to under-identify the model with inadequate degrees of freedom.

An alternative method to validate the single numeric scale is to compare the correlations between the OF-AF gap and the other main model variables reported in table 92 in section 8.4 (which used the factor scores in SPSS arising from the exploratory factor analysis) with OF-AF gap correlations using the numerically calculated values.

This correlation comparison is shown in table 96.

		OF-AF Gap using EFA Factors (from table 92)	OF-AF Gap using Numeric Calculation
Environmental Turbulence	Pearson Correlation	.498**	.527**
	Sig. (2-tailed)	.000	.000
Innovation Propensity	Pearson Correlation	.664**	.702**
	Sig. (2-tailed)	.000	.000
Emergent Strategy Bias	Pearson Correlation	-.433**	-.405**
	Sig. (2-tailed)	.000	.000
Firm Performance	Pearson Correlation	.270**	.312**
	Sig. (2-tailed)	.001	.000

\*\* . Correlation is significant at the 0.01 level (2-tailed).

**Table 96 – OF-AF Gap Correlations**

It can be seen in table 96 that the correlations generated using the OF-AF gap numeric scale developed in this chapter are very similar to those arising from the use of EFA factor scores in section 8.4. All are significant to at least the 0.01 level, have the correct polarity and are similar in magnitude.

Some small difference is to be expected due to the fact that the three SPSS-generated factor scores include small contributions from OF-AF gap variables that are not explicitly identified in the factor extraction tables 84 to 87. In these tables factor contributions less than 0.3 are not shown but are included in the SPSS factor score calculations. The numerically calculated scores are ‘cleaner’ in this respect and only include contributions from the factors with contributions greater than 0.3 in the factor extraction.

It can therefore be concluded that the numerically calculated OF-AF gap value is a good approximation to the EFA factor score generated OF-AF gap value, and has the benefit of being more readily computed directly from survey question responses using a simple software tool, e.g. a spreadsheet.

Having created the numeric scale the distribution of scores from this research’s main survey is shown in figure 48. The frequency distribution demonstrates a good level of discrimination with scores ranging between 39 and 89 around a mean of approximately 72.

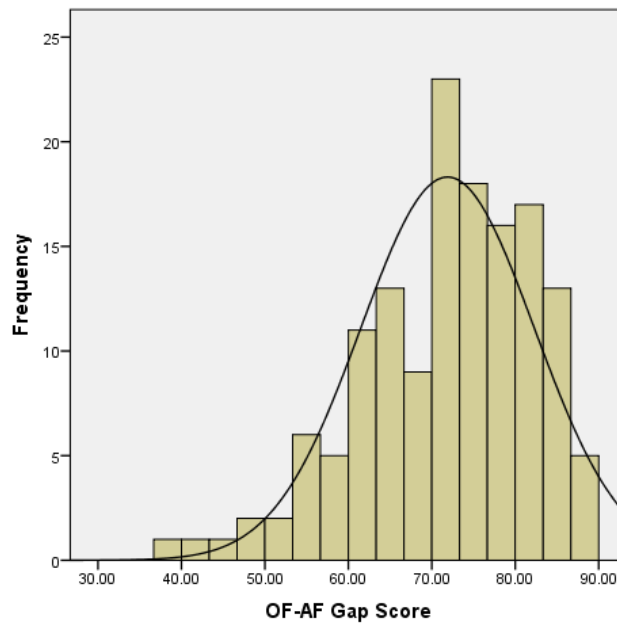


Figure 48 – Distribution of OF-AF Gap Scores

The next section examines OF-AF gap score means across selected demographic splits.

## 10.2 OF-AF Gap Demographic Means

Figure 49 shows the OF-AF gap score means for the industry demographic split. It can be seen that the *Airlines & Aerospace*, *Telecommunications & Electronics* and *Retail & Consumer Durables* categories have the highest OF-AF gap means, while *Defence*, *Food & Beverages* and *Transportation & Delivery* categories have the lowest. The hypotheses supported by this research contend that the greater propensity for innovation in the former industries leads to the development of larger OF-AF gap scores (by c15%) than is observed in the latter industries.

Figure 50 shows the OF-AF gap score means for the number of company employees split. There appears to be negative correlation between the number of employees and the size of the OF-AF gap score. It may be that in larger businesses prescriptive organisational systems and investment rules focus senior management teams primarily on the efficient use of assets which limits the opportunity to develop flexibility and agility to respond to turbulent environments.

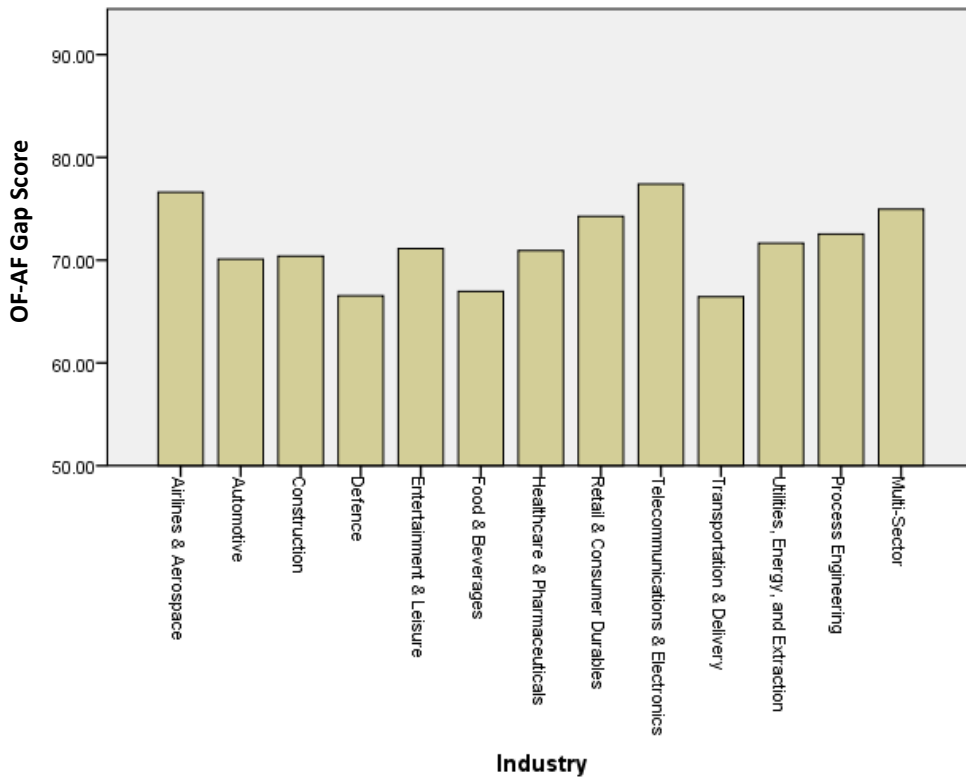


Figure 49 – OF-AF Gap Scores by Industry

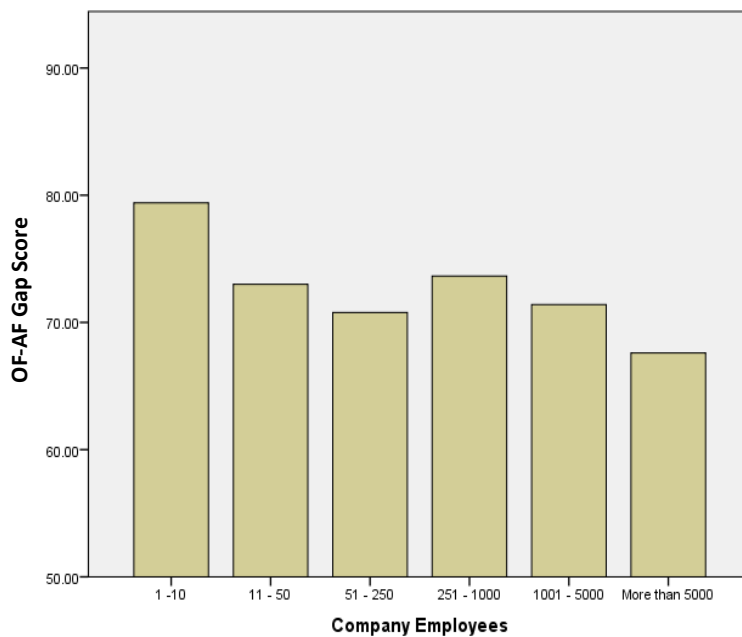


Figure 50 – OF-AF Gap Scores by Number of Company Employees

The OF-AF gap means for the R&D Investment demographic shown in figure 51 reveal a weak positive correlation. This could be explained by higher levels of R&D investment being linked to a higher propensity for innovation and thus to a larger OF-AF gap.

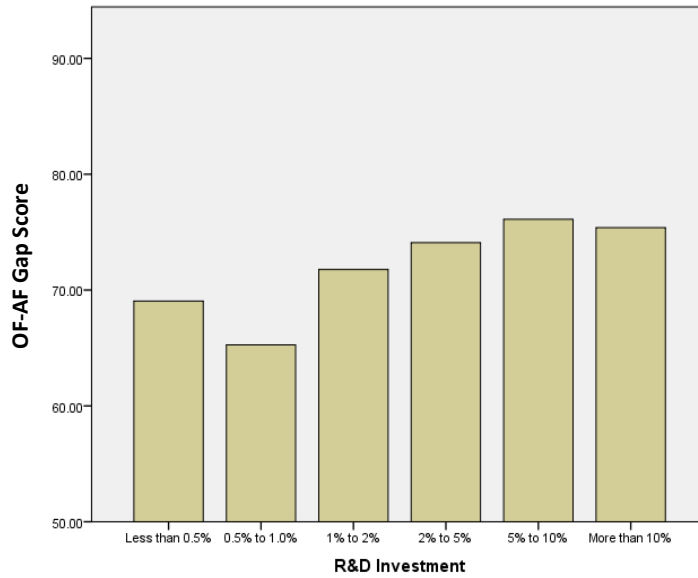


Figure 51 – OF-AF Gap Scores by R&D Investment

Figure 52 shows the OF-AF gap score means for the manufacturing process type split. The size of the OF-AF gap tends to rise across the four process types (make-to-stock MTS, make-to-order MTO, assemble-to-order ATO, and engineer-to-order ETO) as design and process flexibility becomes more critical to success.

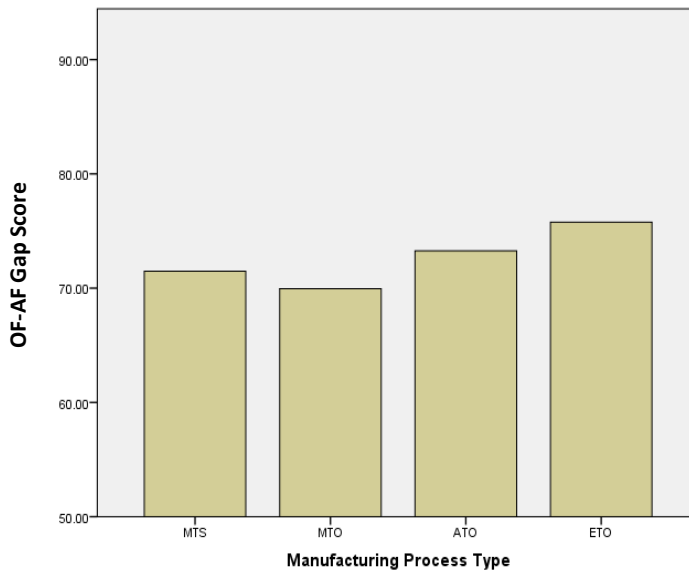


Figure 52 – OF-AF Gap Scores by Manufacturing Process type

This section has shown that the OF-AF gap scale developed in section 10.1 can be used to characterise aspects of companies' demography.

## 10.3 Chapter Summary

This chapter has described the development of a numeric scale representing the size of the OF-AF gap. An individual company's score on this scale can easily be calculated from its survey answers employing simple calculations performed on a readily accessible tool such as a spreadsheet.

The validity of the scale has been tested firstly by comparing the regressions resulting from the original analysis' structural equation model with a structural equation model where the OF-AF gap's three constituent (latent) factors have been replaced with calculated variables. Subsequent verification of the complete scale has been shown by comparing correlations between main model variables and both the original SPSS composite factor score (derived in chapter 8) and the calculated OF-AF gap score developed in this chapter.

The developed numeric scale shows good discrimination across a 0-100 range around a mean of approximately 72 for this sample. OF-AF gap score means have been compared across selected demographic splits and the variations observed can be seen to be consistent with the hypotheses set out in this research.

This accessible scale that characterises the gap between firm's operating and asset frontiers is new to the literature and presents significant opportunities for businesses to analyse their ability to realise their innovative ambition, and what measures they may need to take to improve this ability. This is discussed in the next chapter.

# Chapter 11: Conclusions

The research reported in this thesis is briefly summarised in section 11.1. Conclusions drawn from the research are discussed in section 11.2 and the consequent implications for management teams in manufacturing businesses are developed in section 11.3. Finally, the academic contribution and practical impact of this research are presented in sections 11.4 and 11.5 respectively.

## 11.1 Research Summary

The original objective of this research was to examine how the often dynamic nature of innovation can be effectively realised in a manufacturing business where infrastructure, systems and people take significant time to source, develop and become effective. This juxtaposition of the need to be innovatively agile and flexible contrasted with the typically mechanistic processes associated with the development of firm resources, led to the examination of two distinct areas of extant literature in chapter 2.

The review of the innovation and strategic management literature (section 2.2) positioned the management of innovation within the broader landscape of the strategic management of organisations. The focus in these areas is the external environment the business operates in, the turbulence of the technological and market forces that influence strategy development, sometimes driving senior management teams to significantly change their deliberately developed plans in a bid to be responsive and agile.

The review of the manufacturing and resource-based view literature (section 2.3) revealed that operations strategy is typically subservient to corporate strategy, often only playing a reactive role in an organisation's success. The opportunity for manufacturing units to pro-actively contribute to the development of corporate strategy by anticipating medium-term capabilities that would provide competitive advantage is typically overlooked.

The link between these two bodies of literature is evident as the output of the corporate and innovation strategy development process – the product portfolio plan – begins to be effected in the operations arena through asset and resource *orchestration* (section 2.4 and figure 19). This orchestration of existing and new assets is informed and



facilitated by the knowledge and competencies of the senior management team and the manufacturing workforce. It results in changes and reconfigurations of the manufacturing unit's operating and asset frontiers, which in turn facilitate (or constrain) the development of the firm's competitive capabilities.

In seeking to understand how firms who wish to be innovatively agile develop their manufacturing capabilities in a timely manner, this research built a bridge between the two distinct literature areas by examining the relationship between a firm's innovation propensity and its manufacturing performance frontiers – a relationship that has not been explored in the literature to date.

The theoretical arguments developed in chapter 3 proposed that firms with a propensity to innovate should maintain a larger gap between their operating and asset frontiers in order to cater for their innovative efforts, because a larger gap facilitates the development of the 'higher-order' manufacturing competitive capabilities of flexibility and agility.

In order to test this primary proposition and the related hypotheses presented in chapter 3 it was necessary to develop a new metric to the literature which measures the distance between a manufacturing business's operating and asset frontier – its OF-AF gap. The development of the new quantitative metric closely followed guidance in the literature with rigorous criteria for satisfactory reliability and validity derived in chapter 4. Key to this was a thorough examination of the domain of the new construct and the selection of its constituent content-valid items in chapter 5.

A survey questionnaire was constructed in chapter 5 using peer-reviewed question sets for each constituent variable of the OF-AF gap construct, and for the other hypothesis variables to be analysed – innovation propensity, emergent strategy bias, environmental turbulence and firm performance. The survey was piloted in a single organisation in order to determine the optimum target respondent to ensure response consistency (see chapter 6). Several modifications were made to the survey as a consequence of the pilot exercise.

The main survey was sent to 1701 individuals from 638 unique manufacturing companies. 192 responses were received of which 158 have been used in the analysis.

Purification of the new OF-AF gap scale was conducted by a combination of exploratory and confirmatory factor analyses in chapter 8. Multiple tests to confirm the reliability and validity of the new scale were performed and summarised in section 8.3.4. Having established a reliable and valid metric for the distance between operating

and asset frontiers, the primary proposition and the related hypotheses of this research were tested using bivariate correlations and structural equation modelling.

The correlations and regressions arising from the statistical analysis in chapter 8 that were used to test the research hypotheses predominantly had effect sizes in the 'large' range. The size of the survey sample leads to a theoretical margin of error in the wider population of manufacturing businesses of approximately 7%. The 'large' effect sizes coupled with the moderate margin of error confers a good level of generalisability of the conclusions to the wider population.

Finally, in chapter 10, a normalised numeric scale was developed that enables individual company OF-AF gap 'scores' to be simply produced from survey responses. This scale has been shown to be comparable to that produced by the SPSS factor extraction process in chapter 8, and categorical norms generated using it behave in a manner consistent with the literature.

This new OF-AF gap scale is a potentially powerful tool that enables businesses to compare the position of their manufacturing unit with industry norms and to begin to use the picture that this reveals to inform and justify the deliberate development of asset frontiers (see section 11.3).

## 11.2 Conclusions

Relationships between environmental turbulence, innovation propensity and emergent strategy bias already expressed in extant literature have been confirmed in this research [22] [23] [18]. Higher levels of technological and market turbulence cause senior management teams to recognise the inherent threat posed by their environment and the response that evolves is for the business to develop a greater propensity to innovate (H1 & H8).

However, the propensity to innovate that is borne out of increased environmental turbulence is shown by this research not to be reactive or 'knee-jerk' in nature, rather it is exhibited in the form of businesses taking a longer-term perspective, being better prepared for multiple eventualities and developing their business strategy more deliberately (H2). The relationship between innovation propensity and emergent strategy bias appears to be somewhat circularly self-reinforcing. Increased innovation propensity tends to extend the market and technological planning horizon making the firm better prepared to respond to events as they emerge, minimising the need for

emergent strategy development. Conversely, extending the periphery of investigation during deliberate planning processes reveals opportunities for innovation that may otherwise be hidden from view, supporting an innovative posture.

The development of a new reflective-item scale that measures the distance between a manufacturing unit's operating and asset frontiers allows its relationship with innovation propensity to be explored. It can be seen that firms with higher levels of innovation propensity do in fact develop larger OF-AF gaps, as proposed in chapter 3 (H4 & H9).

There is a strong positive correlation between environmental turbulence and the size of the OF-AF gap. However, this relationship is not reflected in the structural equation model, leading to the conclusion that innovation propensity mediates the relationship between environmental turbulence and the size of the OF-AF gap. Similarly, there is a strong negative correlation between emergent strategy bias and the size of the OF-AF gap (H5), and this relationship is also not reflected in the structural equation model. Innovation propensity also mediates this relationship.

The relationship between innovation propensity and business performance, and the effect the size of the OF-AF gap has on it has revealed the most significant result of this research. The strong positive correlation between innovation propensity and business performance (H6) reflects several extant studies in the literature. However, the equally strong *negative* regression in the structural equation model between these variables suggest that innovation propensity in isolation is in fact a *counterproductive* attribute of the senior management team, unless it is accompanied by a correspondingly large OF-AF gap. The size of the OF-AF gap mediates the relationship between innovation propensity and firm performance. The OF-AF gap is an enabler, a catalyst, that allows firms to realise their innovative ambition in turbulent market and technological contexts and in a manufacturing environment where assets and resources typically take time to deploy and become effective.

Having revealed the importance of the OF-AF gap, its size should therefore not be left to chance and means to more pro-actively manage this characteristic of a manufacturing unit should be considered. This is discussed in the next section.

### 11.3 Managerial Implications

Businesses are encouraged to be innovative to ensure long term success [2, 3] and this is often reflected in companies' mission statements and strategic objectives.

However, this research has shown that the laudable intent and ambition to be innovative is insufficient in isolation, and can actually be counterproductive to business performance if the relative position of operating and asset frontiers is not considered.

A greater distance between the operating and asset frontiers allows competitive capabilities to be built cumulatively leading to the higher-order attributes of flexibility and agility to be evident in the manufacturing unit. This research suggests that this flexibility facilitates the realisation of the firm's innovative intent in a timely manner.

Conversely, if the OF-AF gap is not actively managed, but allowed to develop reactively, the development of competitive capabilities can be restricted, leading to capability trade-offs and periods of potential un-competitiveness. The inference from this research is that asset investments arising from specific, project-related needs do extend the asset frontier, but their timing is often too late and equipment specification too project-focussed to meaningfully broaden the OF-AF gap. This is because project-specific investments, almost by definition, do not effectively *anticipate* requirements arising from the innovation propensity of the business.

*So how should senior management teams deliberately manage the distance between the operating and asset frontiers?*

Managers should focus on the three constituent factors of the OF-AF gap that have emerged from this research to ensure that their manufacturing unit has the requisite levels of flexibility and agility to realise its innovative ambition.

### **Learning & Flexibility**

The flexibility elements of this factor (manufacturing flexibility and product portfolio complexity) are consequences, or indicators, of the OF-AF gap construct rather than antecedents (see section 5.2.2.4). Therefore the focus for managers should be on the nature of organisational and individual learning.

Of the factor's three learning items – absorptive capacity, continuous improvement and training – the firm's absorptive capacity plays the most pivotal role. It contributes most significantly to the *Learning & Flexibility* factor (i.e. it has the highest regression loading), and is the only one of the three that considers not only the application of new knowledge, but also the recognition and assimilation of new knowledge. The firm's ability to recognise and understand new knowledge, and to assimilate it, is essential for

the business to envisage future technical advances and to improve its capability to deploy them.

It has been shown in section 2.3.4 that this ability to recognise and assimilate new knowledge cannot be brought into the organisation in a transactional sense but must be deliberately built over time. A deep understanding of the operation's *current* technology and processes is necessary, but insufficient to prepare the organisation for subsequent phases of its capability development. Knowledge must exist beyond that which is strictly needed to operate in order that opportunities to extend capabilities are recognised and can be reliably evaluated.

It is intuitively reasonable that the areas in which management should target their knowledge-acquisition efforts should be adjacent to their existing expertise. Cohen & Levinthal [147] support this, asserting that it is challenging to make technological leaps in knowledge-acquisition because firms have less understanding of technologies the further they are from their existing competences, and there is therefore a correspondingly increased difficulty in accessing and assimilating new knowledge that is remote from current expertise [147, p138].

While firms should progressively expand their knowledge-base in areas adjacent to their current knowledge, these areas should not be targeted arbitrarily from all the potential directions available, but should follow the technological trajectory of the business. In section 2.3.1 a firm's technological trajectory was shown to be shaped by its current '*asset position and the paths available to it*' [91, p518]. So it is incumbent on managers to understand this trajectory and plan knowledge-acquisition activities along it.

In practical terms, the firm's technological roadmap should be developed considering both the external competitive landscape and the contribution the organisation's resource portfolio can bring to its competitive capability. It should cover the predicted evolution of the market and the firm's product and manufacturing technologies over the medium and longer term. The roadmap should be constructed looking as far into the future as possible using techniques such as periphery scanning [92] and scenario planning [94, 95] to improve its robustness, particularly in the later years.

With the technological roadmap in place, managers should plan knowledge-acquisition activities along the technological trajectory, but critically, *ahead* of today's needs. Centres of excellence and associated knowledge management systems can be developed through training and development programmes. These programmes would

draw on expertise from external agencies including academia, trade bodies, current supply chain partners and other technologically-leading organisations.

### **Ambidexterity**

Maintaining a balance between exploitative and explorative activities, thereby demonstrating increased ambidexterity, is the second component of managing the distance between operating and asset frontiers. The challenge of equitably allocating resources between exploitation and exploration given the natural inclination of businesses to focus on short-term exploitative projects was presented in section 2.2.4.1. The resource-allocation process (as described by Christensen [13, p215] and shown in figure 6) is pivotal in filtering inputs from both deliberate and emergent strategy development processes, and it subsequently characterises the profile of investments in new products, processes and asset acquisitions.

A suitably balanced portfolio of projects can be achieved using the portfolio management techniques discussed in section 2.2.3.3, by allocating resources in accordance with 'strategic themes' and in proportions defined by 'strategic buckets' [5, p211] [6, p250]. Although this approach should ensure resources are channelled into explorative activities, it does not necessarily position that explorative activity in fertile ground.

Atuahene-Gima warns that if exploration is directed at areas where the business has limited existing knowledge then the activity is little more than costly experimentation that is unlikely to take root [99, p65]. This phenomenon may be at the heart of the disincentive for businesses to invest sufficiently in explorative activities – the inherently higher risk and typically longer timescale to achieve financial returns when compared to exploitative activities. Both risk and time issues can be mitigated by grounding explorative activities in areas where a degree of knowledge has been assimilated in the business.

If explorative activities are aligned with the developed technological trajectory of the business and, as described above, absorptive capacity has been developed by acquiring and assimilating knowledge along that trajectory ahead of current needs, then the risk associated with these explorative activities will be lower and the time needed to realise their potential will be reduced. The business will have achieved a higher level of flexibility and agility.

## Age of Assets

The third component of managing the distance between operating and asset frontiers is the average age of manufacturing's suite of assets. The development of manufacturing capabilities through investment in new assets was reviewed in section 2.3.5.2. It was shown that asset investments are often viewed by (typically) non-technical senior management teams solely as a means to improve efficiency, and can therefore only be justified once new products are in their growth phase [175, p378]. The potential for new assets to promote the development of production capabilities beyond the narrow, project-specific requirements upon which the investment was justified is not generally considered.

Hayes & Pisano argue that asset investment should be seen as capability-building over time, rather than a series of discrete purchases [180, p79]. Maritan & Lee contend that it is the organisational capability that is created by the investment that transforms the simple equipment purchase into something that can be more valuable to one firm than another thereby contributing to competitive advantage [181, p2612]. In financial terms an 'option value' is created that is the difference between the invoice value for the equipment and the total contribution to competitive capability.

The capability option value which is created by the new investment is created when it is combined with *'firm-specific, non-tradable resources, such as knowledge, skills, and organisational processes'* [181, p2612]. It is this capability option value which contributes to the extension of the asset frontier out in front of the operating frontier, but which is not typically included in asset investment decision-making criteria.

In practical terms, production investments need to satisfy the requirements of both new product developments and the development of the firm's competitive capabilities. It is therefore critical that the capability-building component of asset investments – its *capability option value* – is evaluated and taken into account in investment decisions. If it can be, then the acquisition of equipment that has more capability than immediate project-specific requirements becomes more justifiable in a financial environment where return-on-investment is king.

This *anticipatory* approach to specifying asset investments is in line with the most advanced stage – stage 4 – of Hayes & Wheelwright's model of manufacturing's competitive potential [162, p396] (see table 5 in section 2.3.6.1) which is characterised by:

- *Efforts made to anticipate the potential of new manufacturing practices and technologies.*
- *Long range programmes pursued in order to acquire capabilities in advance of needs.*

This research provides a potential means to access the capability option value of investments that is needed to unlock the anticipatory approach described above. A new metric has been created that assesses the distance between operating and asset frontiers, and has established the beneficial mediating effect it has on the relationship between innovation propensity and firm performance. The positive financial effect of the size of the OF-AF gap (for a given level of innovation propensity and within a particular industry group) could be related back to the age of physical assets and the knowledge acquisition, training and manufacturing flexibility that would accompany such investments. It should therefore be possible to enumerate a capability option value that an asset investment will bring to the business. This numerical analysis to establish the capability option value for specific investments requires further research and is therefore discussed in section 12.2.

## 11.4 Academic Contribution

This research makes the following original contributions to extant literature:

- The link between two distinct bodies of literature – innovation & strategic management and operations strategy & the resource-based view – has been explored by examining the relationship between innovation propensity and manufacturing performance frontiers. This relationship has not been explored in the literature before.
- In terms of research methodology, a pilot survey has been used to establish the optimum respondent profile by examining the response consistency from different respondents' seniority and disciplines from a single organisation. This methodology has not been observed in the quantitative research activity in this research area.
- A new measure has been created and validated that enumerates the distance between a manufacturing business's operating and asset frontiers. Numerical applications of the Theory of Performance Frontiers in the literature have been



limited to the airline industry and these are not more widely applicable across manufacturing industry.

- The relationship between innovation propensity and emergent strategy bias – two attitudinal characteristics of the senior management team – has been explored for the first time and has been shown to be somewhat bi-directional. Managers with a propensity to innovate tend to take a longer-term view reducing the need to react emergently to new information, and those managers planning deliberately expose opportunities to innovate that may otherwise have escaped detection.
- Notwithstanding the positive *correlation* between innovation propensity and firm performance that accords with extant literature, this research uniquely reveals that the relationship is strongly mediated by the size of the OF-AF gap. Indeed, innovation propensity actually has a negative causal effect on firm performance unless it is mediated by the size of the OF-AF gap. This emphasises the need to actively manage this operational attribute.
- A numeric scale has been developed that allows a normalised OF-AF gap score to be easily calculated from an organisation's survey question responses. This allows industry norms for the OF-AF gap to be developed, and comparisons to then be made between those norms and individual company scores and between companies.

## 11.5 Research Impact

This research has the following practical impact on recommended managerial approaches to realising innovative intent in manufacturing businesses.

- The research has established that the distance between a firm's operating and asset frontiers strongly mediates the relationship between innovation propensity and business performance. A larger OF-AF gap creates 'space' for the cumulative development of the higher-order manufacturing capabilities of flexibility and agility, which act as a catalyst for the innovative ambition of the firm. This insight empowers senior management teams to consciously consider the effect of proposed asset investments on the size of the OF-AF gap and the

consequent impact on the firm's ability to innovate in an agile and flexible manner.

- The development of an accessible numeric scale representing the size of the OF-AF gap allows managers to benchmark their business against other companies in their industry and offers the opportunity (following further research) to enumerate the change in OF-AF gap size that could be expected from particular asset investments.
- The constituent factors of the OF-AF gap that have been identified in this research, Learning & Flexibility, Ambidexterity and Age of Assets, provide practical insights that enable managers to develop knowledge acquisition plans, resource allocation processes and asset investment strategies that combine to promote the firm's ability to innovate in an agile and flexible manner.
- A technology roadmap that is developed using techniques to look as far into the future as possible provides the framework to plan and undertake knowledge acquisition activities along its trajectory. By acquiring knowledge *in advance* of that which is strictly required by the business to deliver its current operations, the firm enhances its absorptive capacity and its ability to recognise and evaluate opportunities and threats as they arise. It also provides fertile ground for the explorative activities (including asset investments) to which precious resources are allocated, maximising the chances of success and minimising the time required to deliver that success.
- By considering asset investments as a capability building activity and aligning them with the established technological trajectory, capabilities can be built in advance of those required by the current and imminent product portfolio. This maximises the potential of the manufacturing unit to contribute to the firm's competitive position [162, p396] and creates the agility to deliver on its innovative ambition.
- Specifying and justifying asset investments that deliver capabilities beyond that which is strictly needed is challenging in the financial environment where the return on investment (ROI) metric is ubiquitous. This research has revealed an opportunity to enumerate the capability option value of asset investments that could form part of more enlightened financial evaluations in the future.

## Chapter 12: Limitations & Recommendations

As with any research activity there are limitations to the work described in this thesis and these are discussed in section 12.1 with recommendations to address them presented in section 12.2.1. This is followed in section 12.2.2 by specific suggestions for further research to develop and enhance the recommendations for managerial practitioners proposed in section 11.3.

### 12.1 Research Limitations

The core of this research is a quantitative survey sent to predominantly UK manufacturing businesses. There are a number of limitations associated with the approach and the execution of the survey.

The number of respondents and the completeness of their responses is more than sufficient to support the relatively large effect sizes that arise from the analysis (see section 9.3), and to also support good generalisability to the wider population of manufacturing businesses (see section 9.4). There is therefore a high level of confidence in the general conclusions discussed in section 11.2. However, to take the analysis to a greater level of granularity by looking at different demographic splits (as has been undertaken in chapter 10) the quantity of respondents in each demographic category becomes too small to draw detailed conclusions beyond the general trends discussed in section 10.2. To establish industry norms for the size of the OF-AF gap, as has been suggested in preceding sections of this chapter, a greater sample size would be required.

The geographic spread of survey respondents inevitably reflects the profile of the contact database used to generate the set of potential participants. The contact database mirrors the commercial areas of operation of the software retailer from which it was sourced. It can be seen from table 51 in section 7.4.1 that over 90% of respondents are located in the Midlands (18.3%), Yorkshire (31.6%), the North (29.7%) and Scotland (11.4%). Although there is no reason to suggest that the outcomes of this research are influenced by the location of the organisation, the responses received do originate from a geographically specific area. Confidence in the broad applicability of this research would benefit from the inclusion of organisations with wider geographic and cultural diversity.

The topics addressed in the survey are diverse in nature, covering strategic development, innovation, finance, manufacturing and knowledge-management aspects of the organisation. Likert-style, reflective question sets have been preferred to objective, numeric questions in order that respondents were likely to feel able to respond to every question in the survey. Additionally, steps have been taken to target respondents within businesses that are best-placed to effectively answer the survey by assessing the consistency of responses from multiple individuals from the same company using a pilot survey (see chapter 6). Notwithstanding these measures, there is an assumption that a single individual can adequately assess the broad range of organisational characteristics involved in this research. Further consideration should be given to research methods that could access these characteristics from sources with a more focused expertise.

The discussion in section 9.1 revealed a limitation associated with the survey question designed to assess the degree of asset utilisation within the manufacturing unit. This variable was excluded on statistical grounds as a potential constituent item of the OF-AF gap in section 8.3.1. It was shown that the remaining eight items forming the OF-AF gap continue to adequately represent the domain of the construct and that the subsequent analysis is therefore robust. Due to the identified weaknesses in the form of the asset utilisation survey question, however, there remains some doubt as to whether the variable's statistical exclusion is due to the response inconsistency arising from the question itself, or whether in fact the variable is not a constituent element of the OF-AF gap as has been concluded here. A recommendation in section 11.5.1 will therefore be to explore this issue and seek means to redress the identified limitations.

A critical consideration when creating a new metric to the literature is the demonstration of its construct validity. That is, does it measure the underlying construct it is designed to? This research has closely followed the guidance in the literature in respect of the creation of a new measure. Benchmark criteria for the successful creation of a new measure were established from the literature in section 4.3.6.1 and evidence that those criteria had been satisfied was summarised in table 91 in section 8.3.4. The degree of construct validity demonstrated by this evidence is as great as can be achieved within a single piece of research that develops a new measure. The recommended final step in confirming construct validity is to compare the new measure to other metrics designed to measure the same thing. This is, by definition, not possible within the confines of the research originating the measure, but should be considered by future researchers.

The time constraints associated with this programme of research have led to a cross-sectional approach. A 'snap-shot' view of the model variables has been taken to examine relationships and draw conclusions. A limitation of this approach is that the change in dependent variables over an extended time period resulting from specific managerial decisions cannot be observed. A longitudinal study would be useful to explore the characteristics of a firm's innovation propensity, the size of its OF-AF gap and its associated financial performance both before and after strategic asset investments.

## 12.2 Recommendations

Section 12.2.1 makes recommendations to address the limitations discussed in the previous section, section 12.1. This is followed in section 12.2.2 by specific suggestions for further research to develop and enhance the recommendations for managerial practitioners.

### 12.2.1 Research to Address Current Limitations

The ability to numerically benchmark their OF-AF gap against industry norms has been cited in section 11.3 as a useful tool for managers in assessing their competitive potential. The tentative industry norms suggested by this research's analysis in section 10.2 could be made more robust by obtaining statistically significant quantities of responses in each industry category facilitating more granular analysis.

Prior to simply sending out the survey developed by this research (i.e. the survey in Appendix B) to more targeted individuals from industry sectors of interest, three improvements should be considered.

Firstly, the potential OF-AF gap constituent variable of *asset utilisation* should be reconsidered for inclusion. Research should be undertaken to establish whether there is precedent for measurement of the degree of asset utilisation of the organisation's suite of equipment *when the manufacturing unit is operating at its operating frontier*. The italicised qualification was not made clear in the question used in this research and may have undermined the validity of responses received. From the subsequent analysis a final decision can be made as to whether the exclusion of this variable from the OF-AF gap construct is justified.

Secondly, in order to address the limitations associated with the range of expertise required to answer the complete set of survey questions, consideration should be given to targeting particular sections of the questionnaire to the most appropriate disciplines within surveyed companies. Disciplines to target should include at least finance, marketing, engineering and operations. While this could potentially provide more expert responses, it is recognised that logistically this would be difficult to achieve in the quantities desired and that the likelihood of incomplete responses from a single organisation would increase.

Thirdly, the influence of the manufacturing unit's location on the conclusions of this research should be considered. This research has focussed on the midlands and northern regions of the UK mainland. It would be useful to establish if there is any geographic or cultural variability to the measurement of the OF-AF gap or the industry norms established for it. Further research in other geographic areas should therefore be undertaken, and any cultural differences explored by comparing results of the 'western' economies of the UK, Europe, the US and antipodean countries, with those of countries in the far east.

As has been stated several times, the construct validity of a new metric can only be established to a certain extent within the confines of the single piece of research that originates it. A key recommendation for future research is therefore to reinforce the construct validity of the OF-AF gap construct developed here by seeking to measure the same dimension by other means and analysing the correlation between the two.

Finally, it would be useful to examine the time-based characteristics of the OF-AF gap and its interplay with innovation propensity and firm performance. By repeated use of the survey questionnaire at key points of the technological development of targeted businesses, the evolution of the OF-AF gap and its effect on the competitive capabilities of the manufacturing unit could be examined as assets are acquired and/or disposed of.

### **12.2.2 Research to Enhance Management Practice**

The ability to realise innovative ambition in manufacturing businesses, particularly in turbulent environments, has been shown to be underpinned by an appropriately large distance between its operating and asset frontiers. It is interesting that the analysis has not suggested at which point the size of the OF-AF gap becomes *too* large. As

discussed in chapter 3, Teece et al [212] observe the danger of focussing on agility at the expense of efficiency and call for an optimum balance. It is reasonable to conclude that at some level the OF-AF gap could become too big. Further research should attempt to examine the tipping point where a large OF-AF gap starts to negatively impact firm performance.

Two of the three constituent factors that characterise the OF-AF gap revolve around the organisation's resource allocation process – *ambidexterity* and *age of assets*. Deliberate management of the OF-AF gap therefore requires a clear understanding of resource allocation, which was shown in the literature review to be at the heart of strategy definition and implementation (see figure 6 in section 2.2.5).

Discussion in Section 9.1 concluded that the influence of ambidexterity on the size of the OF-AF gap arises from a subtle combination of the level of resources allocated to explorative and to exploitative activities. Maritan & Lee comment at length on the importance of methods of resource allocation, and in particular how asset investments are valued [181].

*“Models of the resource allocation process typically do not address competitive advantage; the focal outcome is an investment or other resource commitment. Those commitments may be seen to shape firm strategy or aggregate to an emergent strategy, and performance outcomes resulting from the strategy may generate feedback that initiates new resource allocation proposals. But the focus remains on drivers of commitment.” [181, p2613]*

This focus purely on investment against objective commitments (or returns) is at the heart of financial return on investment (ROI) metrics, so ubiquitous in industry. It fails to account for the additional capabilities that an investment brings to the organisation when it is combined with the firm's existing, unique resources.

*“Investments in the tradeable and non-tradeable resources that contribute to capabilities not only support current strategies but also provide a means of responding to future contingent events; that is, they have an option value. As a result, investments made in a capability have both expected returns associated with current strategies based on the capability and potential future returns associated with future uses of that capability, a complex feature that complicates the definition process.” [181, p2612]*

Further research – in the form of detailed case studies – would therefore be beneficial to understand the resource allocation processes of firms demonstrating larger OF-AF gap sizes. Case study research should focus on the methods those firms employ in order to balance resources between explorative and exploitative activities, and whether the ‘capability option value’ of assets is incorporated in the investment decision-making process.

It is likely that firms that try to attribute a capability-building value to a potential asset investment can currently only do this in a subjective manner which carries less weight in financial analyses. This research offers the possibility to enumerate the capability-building value of the investment, thereby making asset investments more attractive. This should lead to the extension of the asset frontier out in front of the operating frontier – widening the OF-AF gap – sooner than would otherwise be the case.

Further research is recommended to explore the financial benefit of the size of the OF-AF gap, in order that a capability option value could be estimated for particular asset investments. By replacing the reflective question set for the business performance variable that has been used in this research with a numeric (currency-based) scale, the positive financial effect of the size of the OF-AF gap could be established (for a given level of innovation propensity and within a particular industry group). The financial effect of the OF-AF gap could then be related back to the age of physical assets and the knowledge acquisition, training and manufacturing flexibility that would accompany such investments.



## Appendices

### Appendix A – Pilot Survey Questionnaire

#### Invitation Email:

**From:** MacKenzie Ian  
**Sent:** 09 June 2016 16:11  
**To:** xxx  
**Subject:** Innovation in Manufacturing Businesses

Good afternoon all,

Some of you may be aware that I am undertaking a part-time PhD at York University in the area of innovation in manufacturing businesses.

Companies are encouraged to be innovative to ensure long term success, but this can be challenging for manufacturing businesses that have high levels of investment in equipment, systems and people that take time to develop and become effective. It is particularly difficult in times of significant market and technological change.

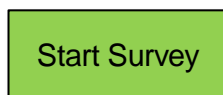
Later in the year I will be conducting an online survey across a range of UK manufacturing businesses to shed light on this critical area.

xxxxx has kindly agreed that I can ask you to be guinea pigs to pilot my survey, before it goes live to a much wider audience.

The survey should take approximately 20-25 minutes to complete and comprises questions with predominantly multiple choice answers.

If you could complete the survey by close of play on Friday 17<sup>th</sup> June that would be much appreciated. In addition to the answers to the questions in the survey, if there any other comments about its format or mechanics then please could you let me know.

Click the button below to start the survey.



Thank you very much for taking part!

Regards  
Ian

## Pilot Survey Questionnaire:

### Introduction

Thank you for agreeing to take part in this questionnaire, which is designed to examine how innovation is managed and nurtured in UK manufacturing businesses.

It should take approximately 20 minutes to complete and it consists predominantly of multiple choice questions.

By completing this questionnaire you are agreeing the information you provide can be used for a postgraduate research project being undertaken at the University of York's Department of Engineering Education & Management.

All data will remain anonymous and your name will not be required.

Please answer all of the questions, thank you.

Ian MacKenzie  
Postgraduate Student  
Department of Engineering Education & Management  
University of York

### About Your Business

The questions on this page relate to general information about your business and your role in it.

1. Which of the following best describes the principal industry of your organisation?
  - Agriculture
  - Airlines & Aerospace
  - Automotive
  - Construction
  - Defence
  - Entertainment & Leisure
  - Food & Beverages
  - Government
  - Healthcare & Pharmaceuticals
  - Retail & Consumer Durables
  - Telecommunications & Electronics
  - Transportation & Delivery
  - Utilities, Energy & Extraction
  - Other (please specify)
  
2. How many years has your company been in business?
  - Less than 5
  - 5 - 10
  - 11 - 15
  - 16 -20
  - Over 20

## Appendix A

3. What is the ownership structure of your business?
  - Publicly traded
  - Privately owned
  - Government
  - Non-profit
  - Other (please specify)
  
4. What is your company's annual sales revenue?
  - Less than £10m
  - £11m - £50m
  - £51m - £100m
  - £101m - £500m
  - More than £500m
  
5. What proportion of sales revenue do you estimate is invested in R&D and product development?
  - Less than 0.5%
  - 0.5% to 1.0%
  - 1% to 2%
  - 2% to 5%
  - 5% to 10%
  - More than 10%
  
6. What is the total number of full-time employees?
  - 1 -10
  - 11 - 50
  - 51 - 250
  - 251-1000
  - 1001 - 5000
  - More than 5000
  
7. What is your position within the company?
  - Director
  - Senior Manager
  - Manager
  - Operational Level
  
8. What business discipline most closely matches your role?
  - General Management
  - Finance
  - Manufacturing
  - Engineering
  - IT
  - Human Resources
  - Other (please specify)

## Appendix A

### Business Environment & Relative Performance

The questions on this page relate to the business environment in which your company operates - in terms of its customers, markets and manufacturing technologies. The relative performance of the business is then considered.

9. When considering the market and technological environment your business operates within, please indicate the extent of your agreement with the following statements:

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
In our kind of business, customers' product preferences change over time	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our customers tend to look for new products all the time	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sometimes our customers are price sensitive, but on other occasions price is relatively unimportant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We are witnessing demand for our products and services from customers who never bought them before	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
New customers tend to have product-related needs that are different from those of our existing customers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We cater to similar customers to those we have in the past	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The technology in our industry is changing rapidly	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Technological changes provide big opportunities in our industry	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
It is very difficult to forecast where the technology in our industry will be in the next two to three years	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
A large number of new product ideas have been made possible through technological breakthroughs in our industry	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Technological developments in our industry are relatively minor	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

10. Please rate your business's performance relative to your major competitors in terms of:

	Much Worse	Worse	Slightly Worse	About the Same	Slightly Better	Better	Much Better
Productivity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Profitability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Market share of major product or product line	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Growth rate in unit sales	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ability to produce a range of products	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

## Appendix A

### Strategic Approach

The questions on this page relate to the role innovation plays in developing the business and then how business strategy is formulated.

11. Please indicate the extent of your agreement with the following statements concerning the role of innovation in your business:

	Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree
Innovation is an underlying culture and not just a word	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our business model is premised on the basis of strategic intent	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our senior managers are able to effectively cascade the innovation message throughout the organisation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We have an innovation vision that is aligned with projects, platforms, or initiatives	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
This organisation's management team is diverse in their thinking in that they have different views as to how things should be done	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
There is a coherent set of innovation goals and objectives that have been articulated	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Innovation is a core value in this organisation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We have continuous strategic initiatives aimed at gaining a competitive advantage	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our strategic planning process is opportunity oriented as opposed to process oriented	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

12. Please indicate the extent of your agreement with the following statements concerning how strategy is developed in your business:

	Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree
We typically don't know what the content of our business strategy should be until we engage in some trial and error actions	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
My business unit's strategy is carefully planned and well understood before any significant competitive actions are taken	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Formal strategic plans serve as the basis for our competitive actions	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
My business unit's strategy is typically not planned in advance but, rather, emerges over time as the best means for achieving our objectives become clearer	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Competitive strategy for my business unit typically results from a formal business planning process (i.e. the formal plan precedes the action)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

## Manufacturing Facilities & Flexibility

The questions on this page relate to your primary manufacturing facility - the complexity of the products and processes it has to contend with and its level of flexibility.

13. Where is your primary manufacturing facility located?

- England – South West
- England – South East
- England – London
- England – East
- England – East Midlands
- England – West Midlands
- England – Yorkshire & the Humber
- England – North East
- England – North West
- Northern Ireland
- Republic of Ireland
- Scotland
- Wales
- Other (please specify)

14. Roughly what percentage of the equipment in this facility falls into each of these five age categories? (please ensure total of entries is 100)

- Less than 2 years old
- 3 – 5 years old
- 6 – 10 years old
- 11 – 20 years old
- Over 20 years old

15. What is the dominant manufacturing process type?

- Make-to-stock
- Make-to-order
- Assemble-to-order
- Engineer-to-order

16. Excluding seasonal factors, by how much is it currently practicable for you to increase your production from your existing plant and equipment without raising unit costs?

- 0%
- 1% - 5%
- 6% - 10%
- 11% - 20%
- Over 20%

## Appendix A

17. How complex are the majority of your company's products?
- Very few distinct components are needed, and the relations between them are simple and clear
  - Few distinct components are needed
  - A moderate number of distinct components are needed
  - A large number of distinct components are needed
  - A very large number of distinct components are needed. They are both closely interrelated and involve complex linkages
18. How complex is the structure of the production processes for the majority of the company's products?
- Very few distinct production steps are needed, and the relations between them are simple and clear
  - Few distinct production steps are needed
  - A moderate number of production steps are needed
  - A large number of production steps are needed
  - A very large number of production steps are needed. They are both closely interrelated and involve complex linkages
19. How many core technologies are involved in the development and production of the majority of your company's products? ("Core technologies" as used here may be defined as those product or process technologies that directly affect the company's competitive advantage.)
- Only one core technology
  - Two dissimilar core technologies
  - Three dissimilar core technologies
  - Four dissimilar core technologies
  - More than four dissimilar core technologies
20. How complex is the customer interface for the majority of your company's products?
- No variation in customer expectations.
  - Minor variation in customer expectations
  - Moderate variation in customer expectations, subtle differences in product characteristics are not too important
  - High specificity of customer expectations, subtle differences in product characteristics are important.
  - Very high specificity of customer expectations, subtle differences in product characteristics are of great importance.

## Appendix A

21. When considering the flexibility of your manufacturing facility, please indicate the extent of your agreement with the following statements:

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Our firm can introduce new products efficiently	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our firm can implement many different product modifications	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our firm can implement product modifications efficiently	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our firm's manufacturing system can operate at many high and low production volumes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our firm's manufacturing system can change production volumes efficiently	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our firm's manufacturing system can accommodate many different product mixes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our firm's manufacturing system can change product mixes efficiently	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

### Innovation & Continuous Improvement

The questions on this page relate to the role innovation plays in the operational areas of the business, and then examines attitudes to continuous improvement.

22. Please indicate the extent to which you agree with the following statements relating to the nature of the innovation orientation of your operations during the past 3 years.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Bases its success on its ability to explore new operational technologies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Creates products or services that are innovative to the firm	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Looks for creative ways to satisfy its customers' needs	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Aggressively ventures into new product segments	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Actively seeks new manufacturing technologies and systems	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Actively targets new customer groups	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Commits to improve quality and lower cost	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Continuously improves the reliability of its products and services	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Increases the levels of automation in its operations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Constantly surveys existing customers' satisfaction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Fine-tunes operational activities to keep its current customers satisfied	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Continuously improves existing operational processes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>



## Appendix A

23. Please indicate the extent of your agreement with the following statements relating to continuous improvement in your business:

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
We strive to continually improve all aspects of products and processes, rather than taking a static approach	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We search for continued learning and improvement, after the installation of new equipment	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Continuous improvement makes our performance a moving target, which is difficult for competitors to attack	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We believe that improvement of a process is never complete; there is always room for more incremental improvement	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our organisation is not a static entity, but engages in dynamically changing itself to better serve its customers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

### Training & Knowledge Management

The questions on this page relate to training, organisational learning and knowledge management within the business.

24. When considering organisational learning, please indicate the extent of your agreement with the following statements:

	Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree
The organisation has learned or acquired much new and relevant knowledge over the last three years	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Organisational members have acquired critical capacities and skills over the last three years	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The organisation's performance has been influenced by new learning it has acquired over the last three years	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The organisation is a learning organisation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Appendix A

25. Please indicate the extent of your agreement with the following statements that concern knowledge management:

	Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree
Our unit has frequent interactions with corporate headquarters to acquire new knowledge	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Employees of our unit regularly visit other branches	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We collect industry information through informal means	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other divisions of our company are rarely visited	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our unit periodically organises special meetings with customers or third parties to acquire new knowledge	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Employees regularly approach third parties such as accountants, consultants or tax consultants	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We are slow to recognise shifts in our market (e.g. competition, regulation, demography)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
New opportunities to serve our clients are quickly understood	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We quickly analyse and interpret changing market demands	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

26. Please indicate the extent of your agreement with the following statements that also concern knowledge management:

	Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree
Our unit regularly considers the consequences of changing market demands in terms of new products & services	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Employees record and store newly acquired knowledge for future reference	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our unit quickly recognizes the usefulness of new external knowledge to existing knowledge	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Employees rarely share practical experiences	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We work hard to seize the opportunities for our unit from new external knowledge	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our unit periodically meets to discuss consequences of market trends and new product development	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
It is well known how activities within our unit should be performed	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Client complaints fall on deaf ears in our unit	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our unit has a clear division of roles and responsibilities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We constantly consider how to better exploit knowledge	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our unit has difficulty implementing new products and services	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Employees have a common language regarding our products and services	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

## Appendix A

27. Could you please indicate the approximate time taken to complete this questionnaire?

Thank you for taking the time to complete this questionnaire. If you have any queries please don't hesitate to contact Ian MacKenzie by telephone on xxxxx, or by email at [ids504@york.ac.uk](mailto:ids504@york.ac.uk)

Thank you

Ian MacKenzie  
Postgraduate Student  
Department of Engineering Education & Management  
University of York

## Appendix B – Main Survey Questionnaire

### Invitation Email:

**Subject:** Innovation in Manufacturing Survey

Dear [First Name],

Please excuse this unsolicited email. I am a postgraduate researcher with the Engineering Management Research Group at the University of York. I am conducting research into the nature of innovation in manufacturing businesses.

All companies are encouraged to be innovative to ensure long term success, but this can be particularly challenging for manufacturing businesses that have high levels of investment in equipment, systems and people which take time to develop and become effective. It is especially difficult in times of significant market and technological change.

I am conducting a survey of UK manufacturing businesses to shed light on this critical area and would very much appreciate your input.

The survey should take approximately 20 minutes to complete and is comprised of predominantly multiple choice questions. All individual answers will be kept confidential.

Click the hyperlink below to start the survey. The survey format is compatible with PC, MAC, tablets and smartphones.

[Start Survey](#)

If you have any questions on my research please do not hesitate to contact me.

Thank you very much for taking part!

Ian MacKenzie  
Postgraduate Researcher  
Engineering Management Research Group  
University of York

## Reminder Email:

**Subject:** Innovation in Manufacturing Survey

Dear [First Name],

I recently sent you an email asking you to take part in some postgraduate research into the role innovation plays in UK manufacturing businesses by taking an online survey.

Please accept my apologies if you have already taken the survey, but if you have not then could I encourage you to do so? Incorporating your feedback in this research will create a more complete and richer picture of this critical business area.

The survey should take approximately 20 minutes to complete and is comprised of predominantly multiple choice questions. All individual answers will be kept confidential.

Click the hyperlink below to start the survey. The survey format is compatible with PC, MAC, tablets and smartphones.

[Start Survey](#)

If you have any questions on my research please do not hesitate to contact me.

Thank you very much for taking part!

Ian MacKenzie  
Postgraduate Researcher  
Engineering Management Research Group  
University of York

## Final Reminder Email:

**Subject:** Innovation in Manufacturing Survey

Dear [First Name],

I have previously sent you a couple of emails asking you to take an online survey to inform research into the role innovation plays in UK manufacturing businesses.

If you have not taken the survey could I encourage you to do so? **This is the final call and I will not send any further emails.**

Incorporating your feedback in this research will create a more complete and richer picture of this critical business area.

The survey should take approximately 20 minutes to complete and is comprised of predominantly multiple choice questions. All individual answers will be kept confidential.

Click the hyperlink below to start the survey. The survey format is compatible with PC, MAC, tablets and smartphones.

**[Start Survey](#)**

If you have any questions on my research please do not hesitate to contact me.

Thank you very much for taking part!

Ian MacKenzie  
Postgraduate Researcher  
Engineering Management Research Group  
University of York

## Main Survey Questionnaire:

### Introduction

Thank you for agreeing to take part in this questionnaire, which is designed to examine how innovation is managed and nurtured in UK manufacturing businesses.

It should take approximately 20 minutes to complete and it consists predominantly of multiple choice questions.

By completing this questionnaire you are agreeing the information you provide can be used for a postgraduate research project being undertaken at the University of York's Engineering Management Research Group.

All data will remain anonymous and your name will not be required. Your company name is requested in order that multiple responses from the same company can be accounted for. Individual responses will be kept confidential and only aggregated responses will be published. If you have any queries please don't hesitate to contact me by email at [idm504@york.ac.uk](mailto:idm504@york.ac.uk)

Please answer all of the questions, thank you.

Ian MacKenzie  
Postgraduate Student  
Engineering Management Research Group  
University of York

### **The questions on this first page relate to general information about your business and your role in it.**

Q1. What is the ownership structure of your business?

- Publicly traded
- Privately owned
- Government
- Non-profit
- Other (please specify) \_\_\_\_\_

Q2. Which of the following organisation structures most closely fits your own?

- Your business has its own manufacturing facility and is not a subsidiary of a larger group of companies.
- Your business has its own manufacturing facility, and is a subsidiary of a larger group of companies.
- Your business is a subsidiary of a larger group of companies and shares its manufacturing facility with some or all of those companies.

## Appendix B

Q2A. Where is your ultimate parent company's head office located?

- UK
- EU
- US
- Other (please specify) \_\_\_\_\_

Q2B. What is the total number of full-time employees in your group of companies?

- 1 - 250
- 251 - 1000
- 1001 - 5000
- More than 5000

**Please answer all the rest of the questions in the survey from the perspective of the business you directly work for and the primary manufacturing facility that it uses.**

Q3. What is the total number of full-time employees in your company?

- 1 -10
- 11 - 50
- 51 - 250
- 251 - 1000
- 1001 - 5000
- More than 5000

Q4. What is your company's annual sales revenue?

- Less than £10m
- £11m - £50m
- £51m - £100m
- £101m - £500m
- More than £500m

Q5. What proportion of this sales revenue do you estimate is invested in research, new product development and the continuous development of existing products?

- Less than 0.5%
- 0.5% to 1.0%
- 1% to 2%
- 2% to 5%
- 5% to 10%
- More than 10%



## Appendix B

Q6. Which of the following best describes the principal industry that your manufacturing business serves?

- Agriculture
- Airlines & Aerospace
- Automotive
- Construction
- Defence
- Entertainment & Leisure
- Food & Beverages
- Government
- Healthcare & Pharmaceuticals
- Retail & Consumer Durables
- Telecommunications & Electronics
- Transportation & Delivery
- Utilities, Energy, and Extraction
- Other (please specify) \_\_\_\_\_

Q7. How many years has your company been in business?

- Less than 5
- 5 - 10
- 11 - 15
- 16 - 20
- Over 20

Q8. What is your position within the company?

- Director
- Senior Manager
- Manager
- Operational Level

Q9. What business discipline most closely matches your role?

- General Management
- Engineering
- Manufacturing
- Scheduling & Purchasing
- Sales & Marketing
- Finance
- IT
- Human Resources
- Other (please specify) \_\_\_\_\_

Q10. How long have you worked for this company?

- Less than 1 year
- 1 - 3 years
- 4 - 7 years
- 8 - 15 years
- More than 15 years

## Appendix B

Q11. In order that multiple responses from the same company can be accounted for, please provide the name of your organisation. (Your company name will NOT be identified in any reporting of the results.)

**The questions on this page relate to the business environment in which your company operates – in terms of its customers, markets and manufacturing technologies. The relative performance of the business is then considered.**

Q12. When considering the market and technological environment your business operates within, please indicate the extent of your agreement with the following statements:

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
In our kind of business, customers' product preferences change over time	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our customers tend to look for new products all the time	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sometimes our customers are price sensitive, but on other occasions price is relatively unimportant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We are witnessing demand for our products and services from customers who never bought them before	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
New customers tend to have product-related needs that are different from those of our existing customers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We cater to similar customers to those we have in the past	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The technology in our industry is changing rapidly	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Technological changes provide big opportunities in our industry	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
It is very difficult to forecast where the technology in our industry will be in the next two to three years	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
A large number of new product ideas have been made possible through technological breakthroughs in our industry	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Technological developments in our industry are relatively minor	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q13. Please rate your business's performance relative to your major competitors in terms of:

	Much Worse	Worse	Slightly Worse	About the Same	Slightly Better	Better	Much Better
Productivity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Profitability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Market share of major product or product line	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Growth rate in unit sales	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ability to produce a range of products	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Appendix B

**The questions on this page relate to the role innovation plays in developing the business and then how business strategy is formulated.**

Q14. Please indicate the extent of your agreement with the following statements concerning the role of innovation in your business:

	Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree
Innovation is an underlying culture and not just a word	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our business model is premised on the basis of strategic intent	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our senior managers are able to effectively cascade the innovation message throughout the organisation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We have an innovation vision that is aligned with projects, platforms, or initiatives	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
This organisation's management team is diverse in their thinking in that they have different views as to how things should be done	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
There is a coherent set of innovation goals and objectives that have been articulated	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Innovation is a core value in this organisation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We have continuous strategic initiatives aimed at gaining a competitive advantage	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our strategic planning process is opportunity oriented as opposed to process oriented	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q15. Please indicate the extent of your agreement with the following statements concerning how strategy is developed in your business:

	Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree
We typically don't know what the content of our business strategy should be until we engage in some trial and error actions	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
My business unit's strategy is carefully planned and well understood before any significant competitive actions are taken	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Formal strategic plans serve as the basis for our competitive actions	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
My business unit's strategy is typically not planned in advance but, rather, emerges over time as the best means for achieving our objectives become clearer	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Competitive strategy for my business unit typically results from a formal business planning process (i.e. the formal plan precedes the action)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**The questions on this page relate to your primary manufacturing facility - the complexity of the products and processes it has to contend with and its level of flexibility.**

Q16. Where is your primary manufacturing facility located?

- England - South West
- England - South East
- England - London
- England - East
- England - East Midlands
- England - West Midlands
- England - Yorkshire And The Humber
- England - North East
- England - North West
- Northern Ireland
- Republic of Ireland
- Scotland
- Wales
- Other (please specify) \_\_\_\_\_

Q17. Roughly what percentage of the equipment in this facility falls into each of these five age categories? (please ensure total of entries is 100)

- \_\_\_\_\_ Less than 2 years old
- \_\_\_\_\_ 3 - 5 years old
- \_\_\_\_\_ 6 - 10 years old
- \_\_\_\_\_ 11 - 20 years old
- \_\_\_\_\_ Over 20 years old

Q18. What is the dominant manufacturing process type?

- Make-to-stock
- Make-to-order
- Assemble-to-order
- Engineer-to-order

Q19. Excluding seasonal factors, by how much is it currently practicable for you to increase your production from your existing plant and equipment without raising unit costs?

- 0%
- 1% - 5%
- 6% - 10%
- 11% - 20%
- Over 20%

## Appendix B

Q20. How complex are the majority of your company's products?

- Very few distinct components are needed, and the relations between them are simple and clear
- Few distinct components are needed
- A moderate number of distinct components are needed
- A large number of distinct components are needed
- A very large number of distinct components are needed. They are both closely interrelated and involve complex linkages

Q21. How complex is the structure of the production processes for the majority of the company's products?

- Very few distinct production steps are needed, and the relations between them are simple and clear
- Few distinct production steps are needed
- A moderate number of production steps are needed
- A large number of production steps are needed
- A very large number of production steps are needed. They are both closely interrelated and involve complex linkages

Q22. How many core technologies are involved in the development and production of the majority of your company's products? ("Core technologies" as used here may be defined as those product or process technologies that directly affect the company's competitive advantage.)

- Only one core technology
- Two dissimilar core technologies
- Three dissimilar core technologies
- Four dissimilar core technologies
- More than four dissimilar core technologies

Q23. How complex is the customer interface for the majority of your company's products?

- No variation in customer expectations
- Minor variation in customer expectations
- Moderate variation in customer expectations, subtle differences in product characteristics are not too important
- High specificity of customer expectations, subtle differences in product characteristics are important.
- Very high specificity of customer expectations, subtle differences in product characteristics are of great importance.

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Q24. When considering the flexibility of your manufacturing facility, please indicate the extent of your agreement with the following statements:

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Our firm can introduce new products efficiently	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our firm can implement many different product modifications	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our firm can implement product modifications efficiently	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our firm's manufacturing system can operate at many high and low production volumes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our firm's manufacturing system can change production volumes efficiently	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our firm's manufacturing system can accommodate many different product mixes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our firm's manufacturing system can change product mixes efficiently	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**The questions on this page relate to the role innovation plays in the operational areas of the business, and then examines attitudes to continuous improvement.**

Q25. Please indicate the extent to which you agree with the following statements relating to the nature of the innovation orientation of your operations during the past 3 years.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Bases its success on its ability to explore new operational technologies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Creates products or services that are innovative to the firm	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Looks for creative ways to satisfy its customers' needs	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Aggressively ventures into new product segments	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Actively seeks new manufacturing technologies and systems	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Actively targets new customer groups	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Commits to improve quality and lower cost	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Continuously improves the reliability of its products and services	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Increases the levels of automation in its operations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Constantly surveys existing customers' satisfaction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Fine-tunes operational activities to keep its current customers satisfied	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Continuously improves existing operational processes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

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Q26. Please indicate the extent of your agreement with the following statements relating to continuous improvement in your business:

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
We strive to continually improve all aspects of products and processes, rather than taking a static approach	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We search for continued learning and improvement, after the installation of new equipment	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Continuous improvement makes our performance a moving target, which is difficult for competitors to attack	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We believe that improvement of a process is never complete; there is always room for more incremental improvement	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our organisation is not a static entity, but engages in dynamically changing itself to better serve its customers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**The questions on this page relate to training, organisational learning and knowledge management within the business. This is the last page of the survey.**

Q27. When considering organisational learning, please indicate the extent of your agreement with the following statements:

	Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree
The organisation has learned or acquired much new and relevant knowledge over the last three years	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Organisational members have acquired critical capacities and skills over the last three years	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The organisation's performance has been influenced by new learning it has acquired over the last three years	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The organisation is a learning organisation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

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**Q28. Please indicate the extent of your agreement with the following statements that concern knowledge management:**

	Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree
Our business unit has frequent interactions with corporate headquarters to acquire new knowledge	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Employees of our business unit regularly visit other company sites	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We collect industry information through informal means	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other divisions of our company are rarely visited by employees of our business unit	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our business unit periodically organises special meetings with customers or third parties to acquire new knowledge	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Employees regularly approach third parties such as consultants, industry experts or academic institutions	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We are slow to recognise shifts in our market (e.g. competition, regulation, demography)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
New opportunities to serve our clients are quickly understood	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We quickly analyse and interpret changing market demands	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**Q29. Please indicate the extent of your agreement with the following statements that also concern knowledge management:**

	Strongly Disagree	Moderately Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Moderately Agree	Strongly Agree
Our business unit regularly considers the consequences of changing market demands in terms of new products & services	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Employees record and store newly acquired knowledge for future reference	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our business unit quickly recognizes the usefulness of new external knowledge to existing knowledge	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Employees rarely share practical experiences	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We work hard to seize the opportunities for our business unit from new external knowledge	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our business unit periodically meets to discuss consequences of market trends and new product development	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
It is well known how activities within our business unit should be performed	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Client complaints fall on deaf ears in our business unit	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our business unit has a clear division of roles and responsibilities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We constantly consider how to better exploit knowledge	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Our business unit has difficulty implementing new products and services	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Employees have a common language regarding our products and services	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>



## Appendix B

Thank you for taking the time to complete this questionnaire. If you have any queries please don't hesitate to contact Ian MacKenzie by telephone on xxxxx, or by email at [ids504@york.ac.uk](mailto:ids504@york.ac.uk)

Thank you

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## Appendix C – Un-parcelled Structural Equation Model

Byrne asserts that causality can be tested in full latent models where ‘the researcher can hypothesise the impact of one latent construct on another in the modelling of causal direction’ [233, p6-7]. The causality hypotheses of section 3.2.2.2 relate to the new OF-AF gap construct and the other four main model variables – Environmental Turbulence, Innovation Propensity, Emergent Strategy Bias and Firm Performance. In the structural equation models of section 8.5 the question sets for these four variables have been parcelled into single observable variables to take advantage of the modelling simplification parcelling brings (as described in section 4.3.6.1). This appendix checks that this simplification has not compromised the analysis by un-parcelling the four variables. Figure 53 shows the AMOS output for this arrangement.

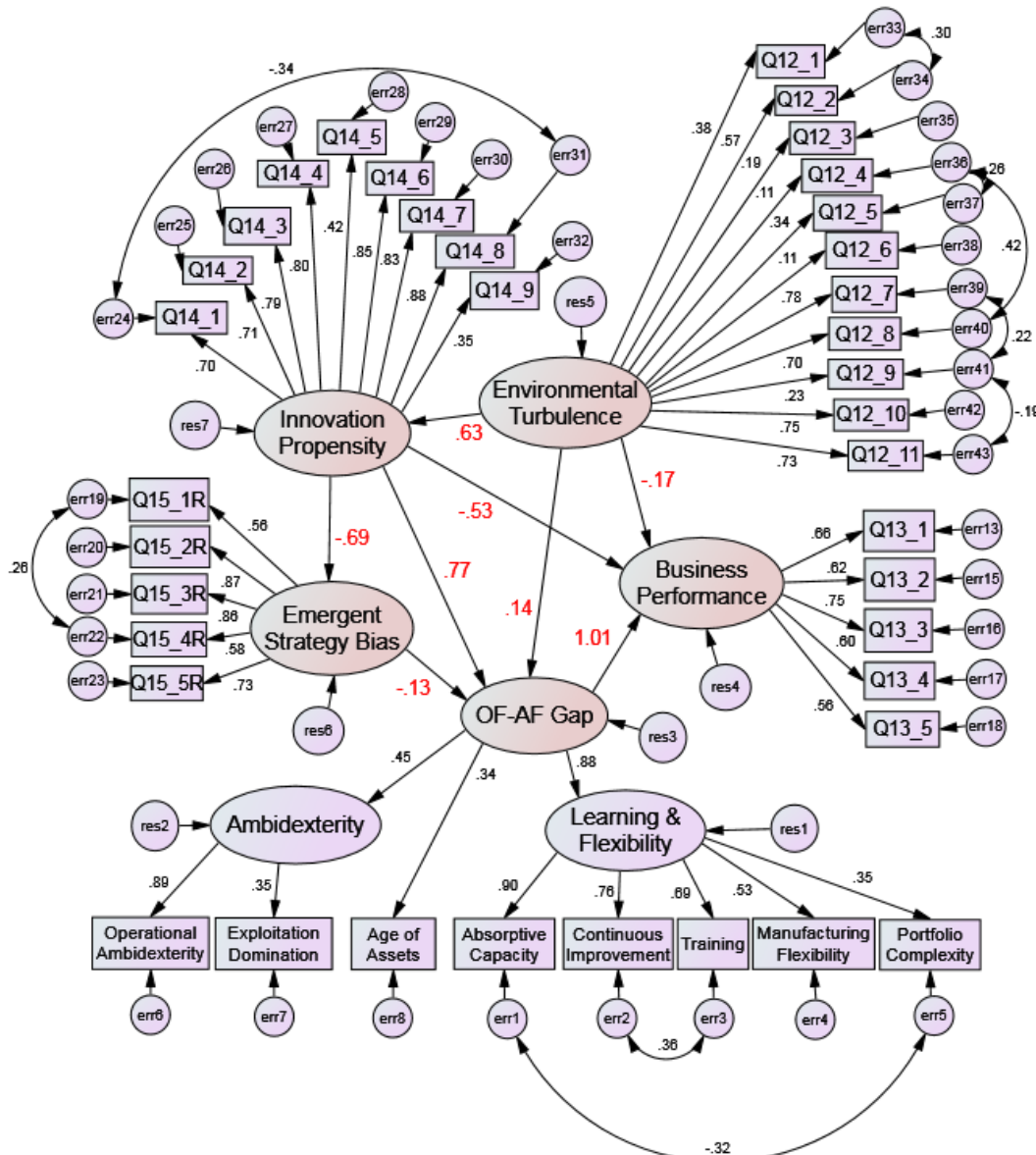


Figure 53 – AMOS Output for Un-Parcelled Variables

## Appendix C

Figure 53 confirms that the parcelling simplification has not compromised the integrity of the regressions between the five variables – and therefore the conclusions that have been drawn.

Each of the four variables is now represented by a latent variable loading onto observable variables for each of the questions in the respective question set. A number of covariances have been added arising from the modification indices of the analysis.

Goodness of fit indices are good for the model with, for example, CFMIN/DF of 1.357, RMSEA of 0.049 and PCLOSE of 0.605.

It can be seen in figure 53 that the regressions between the five latent variables are identical in polarity and very similar in relative magnitude to the parcelled versions of the model in section 8.5. This provides confidence that the simplification introduced by parcelling the questions sets for the four main model variables does not undermine the analysis presented in chapter 8, or the conclusions drawn.

## References

- [1] R. W. Schmenner and M. L. Swink, "On theory in operations management," *Journal of Operations Management*, vol. 17, pp. 97-113, 1998.
- [2] A. Braganza, Y. Awazu, and K. C. Desouza, "Sustaining Innovation Is Challenge For Incumbents," *Research Technology Management*, vol. 52, pp. 46-56, 2009.
- [3] B. Buisson and P. Silberzahn, "Blue Ocean Or Fast-Second Innovation? A Four-Breakthrough Model To Explain Successful Market Domination," *International Journal of Innovation Management*, vol. 14, pp. 359-378, 2010.
- [4] J. Tidd and J. Bessant, *Managing Innovation: Integrating Technological, Market and Organizational Change*, Fifth ed.: Wiley, 2013.
- [5] K. Goffin and R. Mitchell, *Innovation Management: Strategy & Implementation Using the Pentathlon Framework*, 2nd ed.: Palgrave Macmillan, 2010.
- [6] R. G. Cooper, *Winning at new products : creating value through innovation*, 4th ed. New York: Basic Books, 2011.
- [7] G. Vastag, "The theory of performance frontiers," *Journal of Operations Management*, vol. 18, pp. 353-360, 2000.
- [8] S. Brown and K. Blackmon, "Aligning Manufacturing Strategy and Business-Level Competitive Strategy in New Competitive Environments: The Case for Strategic Resonance," *Journal of Management Studies*, vol. 42, pp. 793-815, 2005.
- [9] J. González-Benito and I. Suárez-González, "A Study of the Role Played by Manufacturing Strategic Objectives and Capabilities in Understanding the Relationship between Porter's Generic Strategies and Business Performance," *British Journal of Management*, vol. 21, pp. 1027-1043, 2010.
- [10] C. A. Maritan and G. K. Lee, "Resource Allocation and Strategy," *Journal of Management*, vol. 43, pp. 2411-2420, 2017.
- [11] R. M. Henderson and K. B. Clark, "Architectural innovation: the reconfiguration of existing product technologies and the failure of established firms," *Administrative Science Quarterly*, pp. 9-30, 1990.
- [12] C. M. Christensen, *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*: Harvard Business School Press, 1997.
- [13] C. M. Christensen and M. E. Raynor, *The Innovator's Solution: Creating and Sustaining Successful Growth*: Harvard Business School Press, 2003.
- [14] H.-K. Ellonen, P. Wikström, and A. Jantunen, "Linking dynamic-capability portfolios and innovation outcomes," *Technovation*, vol. 29, pp. 753-762, 2009.
- [15] C. C. Markides and P. A. Geroski, *Fast Second: How Smart Companies Bypass Radical Innovation to Enter and Dominate New Markets*: Wiley, 2004.
- [16] G. C. O'Connor, "Major Innovation as a Dynamic Capability: A Systems Approach," *Journal of Product Innovation Management*, vol. 25, pp. 313-330, 2008.
- [17] B. Kaafarani and J. Stevenson, "Breaking Away: An Innovation Model For Sustainable Growth," *Research Technology Management*, vol. 54, pp. 44-51, 2011.
- [18] "BS 7000-1, Design Management Systems - Guide to Managing Innovation," ed: British Standards Institution, 2008.

- [19] "Changing the Game: Understanding Breakthrough Innovation," *Research Technology Management*, vol. 53, pp. 67-69, 2010.
- [20] C. A. O'Reilly and M. L. Tushman, "The Ambidextrous Organization," *Harvard Business Review*, vol. 82, pp. 74-81, 2004.
- [21] M. Kodama and T. Shibata, "Strategy transformation through strategic innovation capability – a case study of Fanuc," *R&D Management*, vol. 44, pp. 75-103, 2014.
- [22] J. Bessant and D. Francis, "Dealing with discontinuity: how to sharpen up your innovation act," *AIM Research*, 2005.
- [23] W. Phillips, H. Noke, J. Bessant, and R. Lamming, "Beyond the steady state: managing discontinuous product and process innovation," *International Journal of Innovation Management*, vol. 10, pp. 175-196, 2006.
- [24] R. Adner and R. Kapoor, "Innovation ecosystems and the pace of substitution: Re-examining technology S-curves," *Strategic Management Journal*, vol. 37, pp. 625-648, 2016.
- [25] M. L. Tushman and P. Anderson, "Technological discontinuities and organizational environments," *Administrative Science Quarterly*, pp. 439-465, 1986.
- [26] P. Anderson and M. L. Tushman, "Technological discontinuities and dominant designs: A cyclical model of technological change," *Administrative Science Quarterly*, pp. 604-633, 1990.
- [27] J. M. Utterback, *Mastering the Dynamics of Innovation*: Harvard Business School Press, 1994.
- [28] H. Chesbrough, *Open Business Models*: Harvard Business Review Press, 2006.
- [29] T. Johnsen, W. Phillips, N. Caldwell, and M. Lewis, "Centrality of customer and supplier interaction in innovation," *Journal of Business Research*, vol. 59, pp. 671-678, 2006.
- [30] D. Tranfield, M. Young, D. Partington, J. Bessant, and J. Sapsed, "Knowledge management routines for innovation projects: developing a hierarchical process model," *International Journal of Innovation Management*, vol. 7, pp. 27-49, 2003.
- [31] R. G. Cooper and S. J. Edgett, *Product Innovation and Technology Strategy*: Product Development Institute, 2009.
- [32] P. Mugge and S. Markham, "An Innovation Management Framework: A model for managers who want to grow their businesses," in *The PDMA Handbook of New Product Development*, K. B. Kahn, Ed., 3rd ed: Wiley, 2012, pp. 35-50.
- [33] E. Nybakk and J. I. Jenssen, "Innovation Strategy, Working Climate, And Financial Performance In Traditional Manufacturing Firms: An Empirical Analysis," *International Journal of Innovation Management*, vol. 16, pp. 1250008-1-1250008-26, 2012.
- [34] G. Johnson and K. Scholes, *Exploring Corporate Strategy*, Third ed.: Prentice Hall, 1993.
- [35] R. Phaal, C. J. P. Farrukh, and D. R. Probert, "Strategic Roadmapping: A Workshop-based Approach for Identifying and Exploring Strategic Issues and Opportunities," *Engineering Management Journal*, vol. 19, pp. 3-12, 2007.
- [36] R. E. Albright and T. A. Kappel, "Roadmapping in the corporation," *Research-Technology Management*, vol. 46, pp. 31-40, Mar-Apr 2003.
- [37] G. Katz, "Rethinking the Product Development Funnel," *PDMA Visions*, vol. 35, pp. 24-31, 2011.
- [38] R. Cotterman, A. Fuschfeld, P. Henderson, J. Leder, C. Loweth, and A. Metoyer, "Aligning Marketing And Technology To Drive Innovation," *Research Technology Management*, vol. 52, pp. 14-20, 2009.
- [39] H. W. Chesbrough, *Open Innovation: The New Imperative for Creating and Profiting from Technology*: Harvard Business School Press, 2003.

- [40] W. C. Kim and R. Mauborgne, *Blue Ocean Strategy: How to Create Uncontested Market Space and Make the Competition Irrelevant*. Harvard Business Review Press, 2004.
- [41] R. G. Cooper, *Winning at new products : accelerating the process from idea to launch*, 2nd ed. Reading, Mass.: Addison-Wesley, 1993.
- [42] G. S. Lynn, J. G. Morone, and A. S. Paulson, "Marketing and Discontinuous Innovation: The Probe and Learn Process," *California Management Review*, vol. 38, pp. 8-37, Spring96 1996.
- [43] J. Bessant, B. Von Stamm, K. M. Moeslein, and A.-K. Neyer, "Backing outsiders: selection strategies for discontinuous innovation," *R&D Management*, vol. 40, pp. 345-356, 2010.
- [44] H. Florén and J. Frishammar, "From preliminary ideas to corroborated product definitions: managing the front end of new product development," *California Management Review*, vol. 54, pp. 20-43, 2012.
- [45] P. A. Koen, H. Bertels, I. R. Elsum, M. Orroth, and B. L. Tollett, "Breakthrough Innovation Dilemmas," *Research Technology Management*, vol. 53, pp. 48-51, 2010.
- [46] D. Matheson, "Find Pearls & Drive More Innovation in Your Portfolio," *PDMA Visions*, vol. 37, pp. 22-27, 2013.
- [47] R. G. Cooper, "What's Next? After Stage-Gate," *Research Technology Management*, vol. 57, pp. 20-31, 2014.
- [48] P. J. Holahan, Z. Z. Sullivan, and S. K. Markham, "Product Development as Core Competence: How Formal Product Development Practices Differ for Radical, More Innovative, and Incremental Product Innovations," *Journal of Product Innovation Management*, vol. 31, pp. 329-345, 2014.
- [49] D. Edwards, "Innovation Adventures Beyond the Core," *Research Technology Management*, vol. 55, pp. 33-41, 2012.
- [50] A. MacCormack, W. Crandall, P. Henderson, and P. Toft, "Do You Need a New Product-Development Strategy?," *Research Technology Management*, vol. 55, pp. 34-43, 2012.
- [51] R. G. Cooper and A. F. Sommer, "The Agile–Stage-Gate Hybrid Model: A Promising New Approach and a New Research Opportunity," *Journal of Product Innovation Management*, vol. 33, pp. 513-526, 2016.
- [52] A. Richtnér and P. Åhlström, "Top management control and knowledge creation in new product development," *International Journal of Operations & Production Management*, vol. 30, pp. 1006-1031, 2010.
- [53] E. Enkel, O. Gassmann, and H. Chesbrough, "Open R&D and open innovation: exploring the phenomenon," *R&D Management*, vol. 39, pp. 311-316, Sep 2009.
- [54] J. P. Andrew and H. L. Sirkin, "Innovating for cash," *Harvard Business Review*, vol. 81, pp. 76-83, 132, 09/ 2003.
- [55] T. L. Madsen and M. J. Leiblein, "What Factors Affect the Persistence of an Innovation Advantage?," *Journal of Management Studies*, vol. 52, pp. 1097-1127, 2015.
- [56] O. Gassmann, E. Enkel, and H. Chesbrough, "The future of open innovation," *R&D Management*, vol. 40, pp. 213-221, Jun 2010.
- [57] M. Docherty, "Primer on "open innovation." Principles and practice," *PDMA Visions*, vol. 30, pp. 13-17, 2006.
- [58] N. Acur, D. Kandemir, P. C. De Weerd-Nederhof, and M. Song, "Exploring the Impact of Technological Competence Development on Speed and NPD Program Performance," *Journal of Product Innovation Management*, vol. 27, pp. 915-929, 2010.
- [59] N. Acur, D. Kandemir, and H. Boer, "Strategic Alignment and New Product Development: Drivers and Performance Effects," *Journal of Product Innovation Management*, vol. 29, pp. 304-318, 2012.

- [60] R. Calantone and G. Rubera, "When Should RD&E and Marketing Collaborate? The Moderating Role of Exploration–Exploitation and Environmental Uncertainty," *Journal of Product Innovation Management*, vol. 29, pp. 144-157, 2012.
- [61] A. Griffin and A. L. Page, "PDMA Success Measurement Project: Recommended Measures for Product Development Success and Failure," *Journal of Product Innovation Management*, vol. 13, pp. 478-496, 1996.
- [62] C. B. Dobni, "The Relationship Between An Innovation Orientation And Competitive Strategy," *International Journal of Innovation Management*, vol. 14, pp. 331-357, 2010.
- [63] J. G. March, "Exploration and exploitation in organizational learning," *Organization Science*, vol. 2, pp. 71-87, 1991.
- [64] D. A. Levinthal and J. G. March, "The myopia of learning," *Strategic Management Journal*, vol. 14, pp. 95-112, 1993.
- [65] J. Tidd, *From Knowledge Management to Strategic Competence: Assessing Technological, Market and Organisational Innovation*, 3rd ed.: Imperial College Press, 2012.
- [66] Z. Simsek, "Organizational Ambidexterity: Towards a Multilevel Understanding," *Journal of Management Studies*, vol. 46, pp. 597-624, 2009.
- [67] S. Brion, C. Mothe, and M. Sabatier, "The impact of organisational context and competences on innovation ambidexterity," *International Journal of Innovation Management*, vol. 14, pp. 151-178, 2010.
- [68] S. W. Floyd and P. J. Lane, "Strategizing throughout the organization: Managing role conflict in strategic renewal," *Academy of Management Review*, vol. 25, pp. 154-177, 2000.
- [69] C. A. O'Reilly and M. L. Tushman, "Ambidexterity as a dynamic capability: resolving the innovator's dilemma," *Research in organizational behavior*, vol. 28, pp. 185-206, 2008.
- [70] C. Andriopoulos and M. W. Lewis, "Exploitation-exploration tensions and organizational ambidexterity: Managing paradoxes of innovation," *Organization Science*, vol. 20, pp. 696-717, 2009.
- [71] A. K. Gupta, K. G. Smith, and C. E. Shalley, "The interplay between exploration and exploitation," *Academy of Management Journal*, vol. 49, pp. 693-706, 2006.
- [72] S. Raisch, J. Birkinshaw, G. Probst, and M. L. Tushman, "Organizational Ambidexterity: Balancing Exploitation and Exploration for Sustained Performance," *Organization Science*, vol. 20, pp. 685-695, 2009.
- [73] Z. Simsek, C. Heavey, J. F. Veiga, and D. Souder, "A Typology for Aligning Organizational Ambidexterity's Conceptualizations, Antecedents, and Outcomes," *Journal of Management Studies*, vol. 46, pp. 864-894, 2009.
- [74] P. Boumgarden, J. Nickerson, and T. R. Zenger, "Sailing into the wind: Exploring the relationships among ambidexterity, vacillation, and organizational performance," *Strategic Management Journal*, vol. 33, pp. 587-610, 2012.
- [75] T. Swift, "The perilous leap between exploration and exploitation," *Strategic Management Journal*, vol. 37, pp. 1688-1698, 2016.
- [76] C. B. Gibson and J. Birkinshaw, "The antecedents, consequences, and mediating role of organizational ambidexterity," *Academy of Management Journal*, vol. 47, pp. 209-226, 2004.
- [77] M. De Visser, P. de Weerd-Nederhof, D. Faems, M. Song, B. Van Looy, and K. Visscher, "Structural ambidexterity in NPD processes: a firm-level assessment of the impact of differentiated structures on innovation performance," *Technovation*, vol. 30, pp. 291-299, 2010.
- [78] O. Gassmann, B. Widenmayer, and M. Zeschky, "Implementing radical innovation in the business: the role of transition modes in large firms," *R&D Management*, vol. 42, pp. 120-132, 2012.

- [79] F. Blindenbach-Driessen and J. van den Ende, "The Locus of Innovation: The Effect of a Separate Innovation Unit on Exploration, Exploitation, and Ambidexterity in Manufacturing and Service Firms," *Journal of Product Innovation Management*, vol. 31, pp. 1089-1105, 2014.
- [80] I. P. McCarthy and B. R. Gordon, "Achieving contextual ambidexterity in R&D organizations: a management control system approach," *R&D Management*, vol. 41, pp. 240-258, 2011.
- [81] L. A. Berghman, "Strategic Innovation In Established Companies: An Empirical Study Of Appropriate Ambidexterity Strategies," *International Journal of Innovation Management*, vol. 16, pp. 1250007-1-1250007-30, 2012.
- [82] B. Durisin and G. Todorova, "A Study of the Performativity of the "Ambidextrous Organizations" Theory: Neither Lost in nor Lost before Translation," *Journal of Product Innovation Management*, vol. 29, pp. 53-75, 2012.
- [83] P. C. Patel, J. G. Messersmith, and D. P. Lepak, "Walking The Tightrope: An Assessment Of The Relationship Between High-Performance Work Systems And Organizational Ambidexterity," *Academy of Management Journal*, vol. 56, pp. 1420-1442, 2013.
- [84] M. H. Lubatkin, Z. Simsek, Y. Ling, and J. F. Veiga, "Ambidexterity and performance in small-to medium-sized firms: The pivotal role of top management team behavioral integration," *Journal of Management*, vol. 32, pp. 646-672, 2006.
- [85] M. S. Zschocke, B. Mantin, and E. M. Jewkes, "The Effect of Competition on R&D Portfolio Investments," *Production and Operations Management*, vol. 23, pp. 1439-1449, 2014.
- [86] C. K. Prahalad, "The blinders of dominant logic," *Long Range Planning*, vol. 37, pp. 171-179, 2004.
- [87] I. J. Petrick and R. Martinelli, "Driving Disruptive Innovation," *Research Technology Management*, vol. 55, pp. 49-57, 2012.
- [88] C. Gilbert and J. L. Bower, "Disruptive change. When trying harder is part of the problem," *Harvard Business Review*, vol. 80, pp. 94-101, 134, May 2002.
- [89] C. G. Gilbert, "Unbundling the structure of inertia: Resource versus routine rigidity," *Academy of Management Journal*, vol. 48, pp. 741-763, 2005.
- [90] M. E. Porter, *Competitive Strategy*. Free Press, New York, 1980.
- [91] D. J. Teece, G. Pisano, and A. Shuen, "Dynamic capabilities and strategic management," *Strategic Management Journal*, vol. 18, pp. 509-533, 1997.
- [92] G. S. Day and P. J. H. Schoemaker, "Scanning the periphery," *Harvard Business Review*, vol. 84, pp. 161-161, Feb 2006.
- [93] J. Nicholas, A. Ledwith, and J. Bessant, "Reframing the Search Space for Radical Innovation," *Research Technology Management*, vol. 56, pp. 27-44, 2013.
- [94] P. Schwartz, *The art of the long view: planning for the future in a uncertain world.*: Doubleday, 1996.
- [95] C. Christensen, S. Anthony, and E. A. Roth, *Seeing What's Next: Using the Theories of Innovation to Predict Industry Change*: Harvard Business Review Press, 2013.
- [96] J. B. Quinn, "An incremental approach to strategic change," *The McKinsey Quarterly*, pp. 34-52, 1980.
- [97] H. Mintzberg, "Patterns in strategy formation," *Management science*, vol. 24, pp. 934-948, 1978.
- [98] L. Mirabeau and S. Maguire, "From autonomous strategic behavior to emergent strategy," *Strategic Management Journal*, vol. 35, pp. 1202-1229, 2014.
- [99] K. Atuahene-Gima, "Resolving the capability—rigidity paradox in new product innovation," *Journal of Marketing*, vol. 69, pp. 61-83, 2005.



- [100] T. Teichert and R. B. Bouncken, "Rigidities Considered: Supplier Strategies For Integrated Innovation," *International Journal of Innovation Management*, vol. 15, pp. 95-119, 2011.
- [101] Y. Eshima and B. S. Anderson, "Firm growth, adaptive capability, and entrepreneurial orientation," *Strategic Management Journal*, vol. 38, pp. 770-779, 2017.
- [102] R. Bhamra, S. Dani, and T. Bhamra, "Competence understanding and use in SMEs: a UK manufacturing perspective," *International Journal of Production Research*, vol. 49, pp. 2729-2743, 2011.
- [103] M. Augier and D. J. Teece, "Strategy as Evolution with Design: The Foundations of Dynamic Capabilities and the Role of Managers in the Economic System," *Organization Studies*, vol. 29, pp. 1187-1208, 2008.
- [104] J. Barney, "Firm resources and sustained competitive advantage," *Journal of Management*, vol. 17, pp. 99-120, 1991.
- [105] C. A. Maritan and M. A. Peteraf, "Invited Editorial: Building a Bridge Between Resource Acquisition and Resource Accumulation," *Journal of Management*, vol. 37, pp. 1374-1389, 2011.
- [106] I. Dierickx and K. Cool, "Asset Stock Accumulation and Sustainability of Competitive Advantage," *Management Science*, vol. 35, pp. 1504-1511, 1989.
- [107] R. Amit and P. J. H. Schoemaker, "Strategic Assets and Organizational Rent," *Strategic Management Journal*, vol. 14, pp. 33-46, 1993.
- [108] G. Ahuja and R. Katila, "Where Do Resources Come from? The Role of Idiosyncratic Situations," *Strategic Management Journal*, vol. 25, pp. 887-907, 2004.
- [109] M. H. Kunc and J. D. W. Morecroft, "Managerial decision making and firm performance under a resource-based paradigm," *Strategic Management Journal*, vol. 31, pp. 1164-1182, 2010.
- [110] H. A. Ndofor, D. G. Sirmon, and X. He, "Firm resources, competitive actions and performance: investigating a mediated model with evidence from the in-vitro diagnostics industry," *Strategic Management Journal*, vol. 32, pp. 640-657, 2011.
- [111] J. Schmidt and T. Keil, "What makes a resource valuable? Identifying the drivers of firm-idiosyncratic resource value," *Academy of Management Review*, vol. 38, pp. 206-228, 2013.
- [112] B. Wernerfelt, "Invited Editorial: The Use of Resources in Resource Acquisition," *Journal of Management*, vol. 37, pp. 1369-1373, 2011.
- [113] A. Paladino, "Investigating the Drivers of Innovation and New Product Success: A Comparison of Strategic Orientations," *Journal of Product Innovation Management*, vol. 24, pp. 534-553, 2007.
- [114] A. Paladino, "Analyzing the Effects of Market and Resource Orientations on Innovative Outcomes in Times of Turbulence," *Journal of Product Innovation Management*, vol. 25, pp. 577-592, 2008.
- [115] A. Paladino, "Financial Champions and Masters of Innovation: Analyzing the Effects of Balancing Strategic Orientations," *Journal of Product Innovation Management*, vol. 26, pp. 616-626, 2009.
- [116] E. Penrose, *The theory of the growth of the firm*, 1959.
- [117] B. Wernerfelt, "A Resource-Based View of the Firm," *Strategic Management Journal*, vol. 5, pp. 171-180, 1984.
- [118] C. Prahalad and G. Hamel, "The core competence of the corporation," *Harvard Business Review*, 1990.
- [119] D. J. Teece, *Dynamic Capabilities and Strategic Management : Organizing for Innovation and Growth*: Oxford University Press, 2009.
- [120] D. J. Teece, "Dynamic Capabilities: Routines versus Entrepreneurial Action," *Journal of Management Studies*, vol. 49, pp. 1395-1401, 2012.

- [121] H. R. Greve and M.-D. L. Seidel, "The thin red line between success and failure: Path dependence in the diffusion of innovative production technologies," *Strategic Management Journal*, vol. 36, pp. 475-496, 2015.
- [122] D. Leonard-Barton, "Core capabilities and core rigidities: A paradox in managing new product development," *Strategic Management Journal*, vol. 13, pp. 111-125, 1992.
- [123] D. Leonard-Barton, *Wellsprings of knowledge: Building and sustaining the sources of innovation*: Harvard Business Press, 1995.
- [124] J. Tidd and M. J. Trehwella, "Organizational and technological antecedents for knowledge acquisition and learning," *R&D Management*, vol. 27, pp. 359-375, 1997.
- [125] L. R. Newey and S. A. Zahra, "The evolving firm: how dynamic and operating capabilities interact to enable entrepreneurship," *British Journal of Management*, vol. 20, pp. S81-S100, 2009.
- [126] M. J. Benner, "Dynamic or Static Capabilities? Process Management Practices and Response to Technological Change," *Journal of Product Innovation Management*, vol. 26, pp. 473-486, 2009.
- [127] K. M. Eisenhardt and J. A. Martin, "Dynamic capabilities: what are they?," *Strategic Management Journal*, vol. 21, pp. 1105-1121, 2000.
- [128] H.-K. Ellonen, A. Jantunen, and O. Kuivalainen, "The role of dynamic capabilities in developing innovation-related capabilities," *International Journal of Innovation Management*, vol. 15, pp. 459-478, 2011.
- [129] C. E. Helfat and S. G. Winter, "Untangling Dynamic and Operational Capabilities: Strategy for the (N)ever-Changing World," *Strategic Management Journal*, vol. 32, pp. 1243-1250, 2011.
- [130] S. Fainshmidt, A. Pezeshkan, M. Lance Frazier, A. Nair, and E. Markowski, "Dynamic Capabilities and Organizational Performance: A Meta-Analytic Evaluation and Extension," *Journal of Management Studies*, vol. 53, pp. 1348-1380, 2016.
- [131] Y. Y. Kor and A. Mesko, "Dynamic managerial capabilities: Configuration and orchestration of top executives' capabilities and the firm's dominant logic," *Strategic Management Journal*, vol. 34, pp. 233-244, 2013.
- [132] C. E. Helfat and J. A. Martin, "Dynamic Managerial Capabilities: Review and Assessment of Managerial Impact on Strategic Change," *Journal of Management*, vol. 41, pp. 1281-1312, 2015.
- [133] S. Thomke and W. Kuemmerle, "Asset Accumulation, Interdependence and Technological Change: Evidence from Pharmaceutical Drug Discovery," *Strategic Management Journal*, vol. 23, pp. 619-635, 2002.
- [134] D. J. Teece, "Explicating Dynamic Capabilities: The Nature and Microfoundations of (Sustainable) Enterprise Performance," *Strategic Management Journal*, vol. 28, pp. 1319-1350, 2007.
- [135] C. Camisón and A. Villar López, "An examination of the relationship between manufacturing flexibility and firm performance," *International Journal of Operations & Production Management*, vol. 30, pp. 853-878, 2010.
- [136] D. G. Sirmon, M. A. Hitt, and R. D. Ireland, "Managing Firm Resources In Dynamic Environments To Create Value: Looking Inside The Black Box," *Academy of Management Review*, vol. 32, pp. 273-292, 2007.
- [137] D. G. Sirmon and M. A. Hitt, "Contingencies within dynamic managerial capabilities: interdependent effects of resource investment and deployment on firm performance," *Strategic Management Journal*, vol. 30, pp. 1375-1394, 2009.
- [138] C. E. Helfat, S. Finkelstein, W. Mitchell, M. Peteraf, H. Singh, D. Teece, et al., *Dynamic Capabilities: Understanding Strategic Change in Organizations*: Wiley, 2007.
- [139] D. G. Sirmon, M. A. Hitt, R. D. Ireland, and B. A. Gilbert, "Resource Orchestration to Create Competitive Advantage: Breadth, Depth, and Life Cycle Effects," *Journal of Management*, vol. 37, pp. 1390-1412, 2011.

- [140] Y. Li, P. P. Li, H. Wang, and Y. Ma, "How Do Resource Structuring and Strategic Flexibility Interact to Shape Radical Innovation?," *Journal of Product Innovation Management*, vol. 34, pp. 471-491, 2017.
- [141] H.-E. Lin, E. F. McDonough, J. Yang, and C. Wang, "Aligning Knowledge Assets for Exploitation, Exploration, and Ambidexterity: A Study of Companies in High-Tech Parks in China," *Journal of Product Innovation Management*, vol. 34, pp. 122-140, 2017.
- [142] V. Ambrosini, C. Bowman, and N. Collier, "Dynamic Capabilities: An Exploration of How Firms Renew their Resource Base," *British Journal of Management*, vol. 20, pp. S9-S24, 2009.
- [143] M. Zollo and S. G. Winter, "Deliberate Learning and the Evolution of Dynamic Capabilities," *Organization Science*, vol. 13, pp. 339-351, 2002.
- [144] V. Barrales-Molina, Ó. F. Bustinza, and L. J. Gutiérrez-Gutiérrez, "Explaining the Causes and Effects of Dynamic Capabilities Generation: A Multiple-Indicator Multiple-Cause Modelling Approach," *British Journal of Management*, vol. 24, pp. 571-591, 2013.
- [145] J. T. Macher and D. C. Mowery, "Measuring Dynamic Capabilities: Practices and Performance in Semiconductor Manufacturing," *British Journal of Management*, vol. 20, pp. S41-S62, 2009.
- [146] W. M. Cohen and D. A. Levinthal, "Innovation and learning: the two faces of R & D," *The Economic Journal*, pp. 569-596, 1989.
- [147] W. M. Cohen and D. A. Levinthal, "Absorptive Capacity: A New Perspective on Learning and Innovation," *Administrative Science Quarterly*, vol. 35, pp. 128-152, 1990.
- [148] W. M. Cohen and D. A. Levinthal, "Fortune favors the prepared firm," *Management Science*, vol. 40, pp. 227-251, 1994.
- [149] P. J. Lane, B. R. Koka, and S. Pathak, "The reification of absorptive capacity: a critical review and rejuvenation of the construct," *Academy of Management Review*, vol. 31, pp. 833-863, 2006.
- [150] U. Lichtenthaler, "Absorptive Capacity, Environmental Turbulence, And The Complementarity Of Organizational Learning Processes," *Academy of Management Journal*, vol. 52, pp. 822-846, 2009.
- [151] S. A. Zahra and G. George, "Absorptive Capacity: A Review, Reconceptualization, and Extension," *Academy of Management Review*, vol. 27, pp. 185-203, 2002.
- [152] G. Cepeda-Carrion, J. G. Cegarra-Navarro, and D. Jimenez-Jimenez, "The Effect of Absorptive Capacity on Innovativeness: Context and Information Systems Capability as Catalysts," *British Journal of Management*, vol. 23, pp. 110-129, 2012.
- [153] P. C. Patel, M. Kohtamäki, V. Parida, and J. Wincent, "Entrepreneurial orientation-as-experimentation and firm performance: The enabling role of absorptive capacity," *Strategic Management Journal*, vol. 36, pp. 1739-1749, 2015.
- [154] Z. Su, D. Ahlstrom, J. Li, and D. Cheng, "Knowledge creation capability, absorptive capacity, and product innovativeness," *R&D Management*, vol. 43, pp. 473-485, 2013.
- [155] K. Z. Zhou and F. Wu, "Technological capability, strategic flexibility, and product innovation," *Strategic Management Journal*, vol. 31, pp. 547-561, 2010.
- [156] H. Hoang and F. T. Rothaermel, "Leveraging internal and external experience: exploration, exploitation, and R&D project performance," *Strategic Management Journal*, vol. 31, pp. 734-758, 2010.
- [157] C. Weigelt, "The impact of outsourcing new technologies on integrative capabilities and performance," *Strategic Management Journal*, vol. 30, pp. 595-616, 2009.
- [158] A. Parmigiani and W. Mitchell, "Complementarity, capabilities, and the boundaries of the firm: the impact of within-firm and interfirm expertise on concurrent sourcing of complementary components," *Strategic Management Journal*, vol. 30, pp. 1065-1091, 2009.

- [159] M. Zhang, X. Zhao, M. A. Lyles, and H. Guo, "Absorptive capacity and mass customization capability," *International Journal of Operations & Production Management*, vol. 35, pp. 1275-1294, 2015.
- [160] R. Sanchez and J. T. Mahoney, "Modularity, Flexibility, and Knowledge Management in Product and Organization Design," *Strategic Management Journal*, vol. 17, pp. 63-76, 1996.
- [161] J. Foden and H. Berends, "Technology Management At Rolls-Royce," *Research Technology Management*, vol. 53, pp. 33-42, 2010.
- [162] R. H. Hayes and S. C. Wheelwright, *Restoring our Competitive Edge: Competing through Manufacturing*: New York: John Wiley, 1984.
- [163] T. Hill, *Manufacturing Strategy: The Strategic Management of the Manufacturing Function*: Macmillan, London, 1985.
- [164] Y. Liao, F. Deschamps, E. d. F. R. Loures, and L. F. P. Ramos, "Past, present and future of Industry 4.0 - a systematic literature review and research agenda proposal," *International Journal of Production Research*, vol. 55, pp. 3609-3629, 2017.
- [165] R. H. Hayes and G. P. Pisano, "Manufacturing Strategy: At the Intersection of Two Paradigm Shifts," *Production and Operations Management*, vol. 5, pp. 25-41, 1996.
- [166] W. L. Berry, T. Hill, and J. E. Klompmaker, "Aligning marketing and manufacturing strategies with the market," *International Journal of Production Research*, vol. 37, pp. 3599-3618, 1999.
- [167] A. Hill and T. Hill, *Manufacturing Operations Strategy*, Third ed.: Palgrave Macmillan, 2009.
- [168] M. Spring and R. Boaden, "'One more time: how do you win orders?': a critical reappraisal of the Hill manufacturing strategy framework," *International Journal of Operations & Production Management*, vol. 17, pp. 757-779, 1997.
- [169] G. S. Dangayach and S. G. Deshmukh, "Manufacturing strategy," *International Journal of Operations & Production Management*, vol. 21, pp. 884-932, 2001.
- [170] F. P. Williams, D. E. D'Souza, M. E. Rosenfeldt, and M. Kassaei, "Manufacturing strategy, business strategy and firm performance in a mature industry," *Journal of Operations Management*, vol. 13, pp. 19-33, 1995.
- [171] Y. P. Gupta and S. C. Lonial, "Exploring Linkages Between Manufacturing Strategy, Business Strategy, and Organizational Strategy," *Production and Operations Management*, vol. 7, pp. 243-264, 1998.
- [172] P. T. Ward and R. Duray, "Manufacturing strategy in context: environment, competitive strategy and manufacturing strategy," *Journal of Operations Management*, vol. 18, pp. 123-138, 2000.
- [173] J. Gonzalez-Benito and G. Lannelongue, "An integrated approach to explain the manufacturing function's contribution to business performance," *International Journal of Operations & Production Management*, vol. 34, pp. 1126-1152, 2014.
- [174] A. Taylor and M. Taylor, "Operations management research: contemporary themes, trends and potential future directions," *International Journal of Operations & Production Management*, vol. 29, pp. 1316-1340, 2009.
- [175] S. Brown, "An interview with Terry Hill, Emeritus Fellow at the University of Oxford, UK," *International Journal of Operations & Production Management*, vol. 32, pp. 375-384, 2012.
- [176] J. Meredith and M. Vineyard, "A longitudinal study of the role of manufacturing technology in business strategy," *International Journal of Operations & Production Management*, vol. 13, pp. 3-14, 1993.
- [177] C. W. Autry, S. J. Grawe, P. J. Daugherty, and R. G. Richey, "The effects of technological turbulence and breadth on supply chain technology acceptance and adoption," *Journal of Operations Management*, vol. 28, pp. 522-536, 2010.

- [178] Y. Jin, M. Vonderembse, and T. S. Ragu-Nathan, "Proprietary technologies: building a manufacturer's flexibility and competitive advantage," *International Journal of Production Research*, vol. 51, pp. 5711-5727, 2013.
- [179] Y. Yatsenko and N. Hritonenko, "Asset replacement under improving operating and capital costs: a practical approach," *International Journal of Production Research*, vol. 54, pp. 2922-2933, 2016.
- [180] R. H. Hayes and G. P. Pisano, "Beyond World-Class: The New Manufacturing Strategy," *Harvard Business Review*, vol. 72, pp. 77-87, 1994.
- [181] C. A. Maritan and G. K. Lee, "Bringing a Resource and Capability Lens to Resource Allocation," *Journal of Management*, vol. 43, pp. 2609-2619, 2017.
- [182] D. X. Peng, R. G. Schroeder, and R. Shah, "Linking routines to operations capabilities: A new perspective," *Journal of Operations Management*, vol. 26, pp. 730-748, 2008.
- [183] R. G. Schroeder, R. Shah, and D. Xiaosong Peng, "The cumulative capability 'sand cone' model revisited: a new perspective for manufacturing strategy," *International Journal of Production Research*, vol. 49, pp. 4879-4901, 2011.
- [184] M. Swink and W. H. Hegarty, "Core manufacturing capabilities and their links to product differentiation," *International Journal of Operations & Production Management*, vol. 18, pp. 374-396, 1998.
- [185] W. Skinner, "The Focused Factory," *Harvard Business Review*, vol. 52, pp. 113-121, 1974.
- [186] P. R. Richardson, A. J. Taylor, and J. R. M. Gordon, "A Strategic Approach to Evaluating Manufacturing Performance," *Interfaces*, vol. 15, pp. 15-27, Nov-Dec 1985.
- [187] D. Gerwin, "Manufacturing Flexibility: A Strategic Perspective," *Management Science*, vol. 39, pp. 395-410, 1993.
- [188] J. Johansen and J. O. Riis, "The interactive firm – towards a new paradigm," *International Journal of Operations & Production Management*, vol. 25, pp. 202-216, 2005.
- [189] H. Brumme, D. Simonovich, W. Skinner, and L. N. Van Wassenhove, "The Strategy-Focused Factory in Turbulent Times," *Production and Operations Management*, vol. 24, pp. 1513-1523, 2015.
- [190] K. Ferdows and A. De Meyer, "Lasting improvements in manufacturing performance: In search of a new theory," *Journal of Operations Management*, vol. 9, pp. 168-184, 1990.
- [191] M. A. Noble, "Manufacturing strategy: Testing the cumulative model in a multiple country context," *Decision Sciences*, vol. 26, pp. 693-721, 1995.
- [192] A. V. Roth, "Achieving strategic agility through Economies of Knowledge," *Planning Review*, vol. 24, pp. 30-36, 1996.
- [193] N. Liu, A. V. Roth, and E. Rabinovich, "Antecedents and consequences of combinative competitive capabilities in manufacturing," *International Journal of Operations & Production Management*, vol. 31, pp. 1250-1286, 2011.
- [194] M. M. Kristal, X. Huang, and A. V. Roth, "The effect of an ambidextrous supply chain strategy on combinative competitive capabilities and business performance," *Journal of Operations Management*, vol. 28, pp. 415-429, 2010.
- [195] P. C. Patel, S. Terjesen, and D. Li, "Enhancing effects of manufacturing flexibility through operational absorptive capacity and operational ambidexterity," *Journal of Operations Management*, vol. 30, pp. 201-220, 2012.
- [196] J. Tamayo-Torres, A. Ruiz-Moreno, and F. J. Lloréns-Montes, "The influence of manufacturing flexibility on the interplay between exploration and exploitation: the effects of organisational learning and the environment," *International Journal of Production Research*, vol. 49, pp. 6175-6198, 2011.

- [197] J. Tamayo-Torres, J. K. Roehrich, and M. A. Lewis, "Ambidexterity, performance and environmental dynamism," *International Journal of Operations & Production Management*, vol. 37, pp. 282-299, 2017.
- [198] D. X. Peng, R. G. Schroeder, and R. Shah, "Competitive priorities, plant improvement and innovation capabilities, and operational performance," *International Journal of Operations & Production Management*, vol. 31, pp. 484-510, 2011.
- [199] P. J. Singh, F. Wiengarten, A. A. Nand, and T. Betts, "Beyond the trade-off and cumulative capabilities models: alternative models of operations strategy," *International Journal of Production Research*, vol. 53, pp. 4001-4020, 2015.
- [200] M. Thüerer, M. Stevenson, R. Sarmiento, and P. Gianiodis, "On strategic trade-offs: does the principle of energy conservation explain the trade-offs law?," *Management Research Review*, vol. 40, pp. 1163-1174, 2017.
- [201] M. E. Porter, "What Is Strategy?," *Harvard Business Review*, vol. 74, pp. 61-78, 1996.
- [202] H. Boer, M. Holweg, M. Kilduff, M. Pagell, R. Schmenner, and C. Voss, "Making a meaningful contribution to theory," *International Journal of Operations & Production Management*, vol. 35, pp. 1231-1252, 2015.
- [203] E. D. Rosenzweig and A. V. Roth, "Towards a Theory of Competitive Progression: Evidence from High-Tech Manufacturing," *Production and Operations Management*, vol. 13, pp. 354-368, 2004.
- [204] W. Chung and M. Swink, "Patterns of Advanced Manufacturing Technology Utilization and Manufacturing Capabilities," *Production and Operations Management*, vol. 18, pp. 533-545, 2009.
- [205] M. A. Lapré and G. D. Scudder, "Performance Improvement Paths in the U.S. Airline Industry: Linking Trade-offs to Asset Frontiers," *Production & Operations Management*, vol. 13, pp. 123-134, 2004.
- [206] K. Ramdas and J. Williams, "An empirical investigation into the tradeoffs that impact on-time performance in the airline industry," Stanford Graduate School of Business, 2008.
- [207] A. A. Nand, P. J. Singh, and D. Power, "Testing an integrated model of operations capabilities," *International Journal of Operations & Production Management*, vol. 33, pp. 887-911, 2013.
- [208] M. A. Jacobs and M. Swink, "Product portfolio architectural complexity and operational performance: Incorporating the roles of learning and fixed assets," *Journal of Operations Management*, vol. 29, pp. 677-691, 2011.
- [209] S. Cai and Z. Yang, "On the relationship between business environment and competitive priorities: The role of performance frontiers," *International Journal of Production Economics*, vol. 151, pp. 131-145, 2014.
- [210] D. J. Power, "Competence and capability in quality in the high-tech sector: an international comparison," *International Journal of Operations & Production Management*, vol. 34, pp. 1184-1209, 2014.
- [211] R. S. Nason and J. Wiklund, "An Assessment of Resource-Based Theorizing on Firm Growth and Suggestions for the Future," *Journal of Management*, vol. 44, pp. 32-60, 2018.
- [212] D. Teece, M. Peteraf, and S. Leih, "Dynamic Capabilities and Organizational Agility: Risk, Uncertainty and Strategy in the Innovation Economy," *California Management Review*, vol. 58, pp. 13-35, 2016.
- [213] N. Stieglitz, T. Knudsen, and M. C. Becker, "Adaptation and inertia in dynamic environments," *Strategic Management Journal*, vol. 37, pp. 1854-1864, 2016.
- [214] M. Crotty, *The foundations of social science research*: New South Wales: Allen & Unwin, 1998.
- [215] M. Saunders, P. Lewis, and A. Thornhill, *Research methods for business students*, 6th ed.: Pearson Education UK, 2012.

- [216] K. Niglas, "The multidimensional model of research methodology: An integrated set of continua," in *SAGE Handbook of Mixed Methods in Social & Behavioral Research*, A. Tashakkori and C. Teddie, Eds., ed: SAGE Publications, 2010, pp. 215-316.
- [217] B. Blumberg, D. Cooper, and P. Schindler, *Business Research Methods*, 2nd European ed.: New York: McGraw-Hill Education, 2008.
- [218] W. L. Neuman, *Social Research Methods: Qualitative and Quantitative Approaches (4th Edition)*: Allyn & Bacon, 2000.
- [219] G. Burrell and G. Morgan, *Sociological Paradigms and Organisational Analysis*: Heinemann, 1982.
- [220] J. W. Creswell, *Research design: Qualitative, quantitative, and mixed methods approaches*: Sage publications, 2007.
- [221] N. Blaikie, *Designing Social Research*, 2nd ed.: Wiley, 2010.
- [222] R. Suddaby, "What grounded theory is not," *Academy of Management Journal*, vol. 49, pp. 633-43, 2006.
- [223] B. K. Boyd, S. Gove, and M. A. Hitt, "Construct measurement in strategic management research: illusion or reality?," *Strategic Management Journal*, vol. 26, pp. 239-257, 2005.
- [224] G. A. Churchill, "A Paradigm for Developing Better Measures of Marketing Constructs," *Journal of Marketing Research*, vol. 16, pp. 64-73, 1979.
- [225] T. R. Hinkin, "A Review of Scale Development Practices in the Study of Organizations," *Journal of Management*, vol. 21, pp. 967-988, 1995.
- [226] E. R. Thompson, "Individual Entrepreneurial Intent: Construct Clarification and Development of an Internationally Reliable Metric," *Entrepreneurship Theory and Practice*, vol. 33, pp. 669-694, 2009.
- [227] A. Field, *Discovering statistics using IBM SPSS statistics*, 4th ed.: Sage, 2013.
- [228] D. L. Bandalos, "The effects of item parceling on goodness-of-fit and parameter estimate bias in structural equation modeling," *Structural Equation Modeling*, vol. 9, pp. 78-102, 2002.
- [229] K. A. Hagtvet and F. M. Nasser, "How well do item parcels represent conceptually defined latent constructs? A two-facet approach," *Structural Equation Modeling*, vol. 11, pp. 168-193, 2004.
- [230] T. Little, W. Cunningham, G. Shahar, and K. Widaman, "To Parcel or Not to Parcel: Exploring the Question, Weighing the Merits," *Structural Equation Modeling*, vol. 9, pp. 151-173, 2002.
- [231] L. J. Cronbach, "Coefficient alpha and the internal structure of tests," *Psychometrika*, vol. 16, pp. 297-334, 1951.
- [232] P. Panayides, "Coefficient Alpha: Interpret With Caution," *Europe's Journal of Psychology*, vol. 9, pp. 687-696, 2013.
- [233] B. M. Byrne, *Structural Equation Modeling With AMOS: Basic Concepts, Applications, and Programming*, Second ed.: Taylor & Francis, 2010.
- [234] C. A. Schriesheim, K. J. Powers, T. A. Scandura, C. C. Gardiner, and M. J. Lankau, "Improving Construct Measurement In Management Research: Comments and a Quantitative Approach for Assessing the Theoretical Content Adequacy of Paper-and-Pencil Survey-Type Instruments," *Journal of Management*, vol. 19, pp. 385-417, 1993.
- [235] J. C. Anderson and D. W. Gerbing, "Structural equation modeling in practice: A review and recommended two-step approach," *Psychological Bulletin*, vol. 103, p. 411, 1988.
- [236] M. Kohn. (2/9/18). *Correlation Sample Size Calculator*. Available: <http://www.sample-size.net/correlation-sample-size/>

- [237] D. Gefen, D. Straub, and M.-C. Boudreau, "Structural equation modeling and regression: Guidelines for research practice," *Communications of the association for information systems*, vol. 4, p. 7, 2000.
- [238] R. C. MacCallum, K. F. Widaman, S. Zhang, and S. Hong, "Sample size in factor analysis," *Psychological Methods*, vol. 4, p. 84, 1999.
- [239] K. K. Boyer and M. W. Lewis, "Competitive Priorities: Investigating The Need For Trade-Offs In Operations Strategy," *Production and Operations Management*, vol. 11, pp. 9-20, 2002.
- [240] A. M. Knott, D. J. Bryce, and H. E. Posen, "On the Strategic Accumulation of Intangible Assets," *Organization Science*, vol. 14, pp. 192-207, 2003.
- [241] B. Timenes Laugen, N. Acur, H. Boer, and J. Frick, "Best manufacturing practices," *International Journal of Operations & Production Management*, vol. 25, pp. 131-150, 2005.
- [242] E. D. Rosenzweig and G. S. Easton, "Tradeoffs in Manufacturing? A Meta-Analysis and Critique of the Literature," *Production and Operations Management*, vol. 19, pp. 127-141, 2010.
- [243] Q. Tu, M. A. Vonderembse, T. Ragu-Nathan, and T. W. Sharkey, "Absorptive capacity: Enhancing the assimilation of time-based manufacturing practices," *Journal of Operations Management*, vol. 24, pp. 692-710, 2006.
- [244] Z.-L. He and P.-K. Wong, "Exploration vs. Exploitation: An Empirical Test of the Ambidexterity Hypothesis," *Organization Science*, vol. 15, pp. 481-494, 2004.
- [245] P. E. Bierly, F. Damanpour, and M. D. Santoro, "The Application of External Knowledge: Organizational Conditions for Exploration and Exploitation," *Journal of Management Studies*, vol. 46, pp. 481-509, 2009.
- [246] C. L. Wang and M. Rafiq, "Ambidextrous Organizational Culture, Contextual Ambidexterity and New Product Innovation: A Comparative Study of UK and Chinese High-tech Firms," *British Journal of Management*, vol. 25, pp. 58-76, 2014.
- [247] S. Kortmann, C. Gelhard, C. Zimmermann, and F. T. Piller, "Linking strategic flexibility and operational efficiency: The mediating role of ambidextrous operational capabilities," *Journal of Operations Management*, vol. 32, pp. 475-490, 2014.
- [248] S. A. Hill and J. Birkinshaw, "Ambidexterity in corporate venturing: Simultaneously using existing and building new capabilities," in *Academy of Management Proceedings*, 2006, pp. C1-C6.
- [249] C. E. Helfat and M. A. Peteraf, "The dynamic resource-based view: capability lifecycles," *Strategic Management Journal*, vol. 24, pp. 997-1010, 2003.
- [250] D. M. Upton, "The management of manufacturing flexibility," *California management review*, vol. 36, pp. 72-89, 1994.
- [251] J. Nakane, "Manufacturing futures survey in Japan: A comparative survey 1983-1986," *System Science Institute, Waseda University, Tokyo*, 1986.
- [252] A. Tipper and N. Warmke, *Adjusting Productivity Statistics for Variable Capacity Utilisation: Working Harder Or Hardly Working?: Statistics New Zealand*, 2012.
- [253] R. D. Klassen and D. C. Whybark, "The Impact Of Environmental Technologies On Manufacturing Performance," *Academy of Management Journal*, vol. 42, pp. 599-615, 1999.
- [254] R. D. Klassen, "Plant-Level Environmental Management Orientation: The Influence Of Management Views And Plant Characteristics," *Production and Operations Management*, vol. 10, pp. 257-275, 2001.
- [255] R. W. Schmenner and B. H. Rho, "An international comparison of factory productivity," *International Journal of Operations & Production Management*, vol. 10, pp. 16-31, 1990.
- [256] K. E. McKone, R. G. Schroeder, and K. O. Cua, "Total productive maintenance: a contextual view," *Journal of Operations Management*, vol. 17, pp. 123-144, 1999.



- [257] P. Puvanasvaran, H. Megat, T. S. Hong, and M. M. Razali, "The roles of communication process for an effective lean manufacturing implementation," *Journal of industrial engineering and management*, vol. 2, pp. 128-152, 2009.
- [258] N. Jabnoun and K. Sedrani, "TQM, culture, and performance in UAE manufacturing firms," *Quality management journal*, vol. 12, pp. 8-20, 2005.
- [259] C.-L. Yang, S.-P. Lin, Y.-h. Chan, and C. Sheu, "Mediated effect of environmental management on manufacturing competitiveness: an empirical study," *International Journal of Production Economics*, vol. 123, pp. 210-220, 2010.
- [260] S. Caffyn, "Development of a continuous improvement self-assessment tool," *International Journal of Operations & Production Management*, vol. 19, pp. 1138-1153, 1999.
- [261] A. Abdel-Maksoud, D. Dugdale, and R. Luther, "Non-financial performance measurement in manufacturing companies," *The British Accounting Review*, vol. 37, pp. 261-297, 2005.
- [262] S. A. Fernhaber and P. C. Patel, "How do young firms manage product portfolio complexity? The role of absorptive capacity and ambidexterity," *Strategic Management Journal*, vol. 33, pp. 1516-1539, 2012.
- [263] S. Najafi Tavani, H. Sharifi, S. Soleimanof, and M. Najmi, "An empirical study of firm's absorptive capacity dimensions, supplier involvement and new product development performance," *International Journal of Production Research*, vol. 51, pp. 3385-3403, 2013.
- [264] J. J. P. Jansen, F. A. J. Van Den Bosch, and H. W. Volberda, "Managing Potential And Realized Absorptive Capacity: How Do Organizational Antecedents Matter?," *Academy of Management Journal*, vol. 48, pp. 999-1015, 2005.
- [265] J. J. P. Jansen, F. A. J. Van Den Bosch, and H. W. Volberda, "Exploratory Innovation, Exploitative Innovation, and Performance: Effects of Organizational Antecedents and Environmental Moderators," *Management Science*, vol. 52, pp. 1661-1674, 2006.
- [266] M. P. Joshi, R. Kathuria, and S. J. Porth, "Alignment of strategic priorities and performance: an integration of operations and strategic management perspectives," *Journal of Operations Management*, vol. 21, pp. 353-369, 2003.
- [267] M. Kim, N. C. Suresh, and C. Kocabasoglu-Hillmer, "An impact of manufacturing flexibility and technological dimensions of manufacturing strategy on improving supply chain responsiveness: Business environment perspective," *International Journal of Production Research*, vol. 51, pp. 5597-5611, 2013.
- [268] Y. Liu and L. Liang, "Evaluating and developing resource-based operations strategy for competitive advantage: an exploratory study of Finnish high-tech manufacturing industries," *International Journal of Production Research*, vol. 53, pp. 1019-1037, 2015.
- [269] J. P. MacDuffie and K. Sethuraman, "Product Variety and Manufacturing Performance: Evidence from the International Automotive Assembly Plant Study," *Management Science*, vol. 42, pp. 350-369, 1996.
- [270] K. Ramdas, "Managing Product Variety: An Integrative Review And Research Directions," *Production & Operations Management*, vol. 12, pp. 79-101, 2003.
- [271] G. Foster and M. Gupta, "Manufacturing overhead cost driver analysis," *Journal of Accounting and Economics*, vol. 12, pp. 309-337, 1990.
- [272] B. B. Flynn and E. J. Flynn, "Information-Processing Alternatives for Coping with Manufacturing Environment Complexity," *Decision Sciences*, vol. 30, pp. 1021-1052, 1999.
- [273] C. C. Bozarth, D. P. Warsing, B. B. Flynn, and E. J. Flynn, "The impact of supply chain complexity on manufacturing plant performance," *Journal of Operations Management*, vol. 27, pp. 78-93, 2009.
- [274] D. J. Closs, M. A. Jacobs, M. Swink, and G. S. Webb, "Toward a theory of competencies for the management of product complexity: Six case studies," *Journal of Operations Management*, vol. 26, pp. 590-610, 2008.

- [275] C. A. Solberg, "Product Complexity and Cultural Distance Effects on Managing International Distributor Relationships: A Contingency Approach," *Journal of International Marketing*, vol. 16, pp. 57-83, 2008.
- [276] R. Chapman and P. Hyland, "Complexity and learning behaviors in product innovation," *Technovation*, vol. 24, pp. 553-561, 2004.
- [277] F. Langerak, E. J. Hultink, and H. S. J. Robben, "The Impact of Market Orientation, Product Advantage, and Launch Proficiency on New Product Performance and Organizational Performance," *Journal of Product Innovation Management*, vol. 21, pp. 79-94, 2004.
- [278] H.-E. Lin, E. F. McDonough, S.-J. Lin, and C. Y.-Y. Lin, "Managing the Exploitation/Exploration Paradox: The Role of a Learning Capability and Innovation Ambidexterity," *Journal of Product Innovation Management*, vol. 30, pp. 262-278, 2013.
- [279] A. E. Akgün and H. Keskin, "Organisational resilience capacity and firm product innovativeness and performance," *International Journal of Production Research*, vol. 52, pp. 6918-6937, 2014.
- [280] D. P. Slevin and J. G. Covin, "Strategy Formation Patterns, Performance, and the Significance of Context," *Journal of Management*, vol. 23, p. 189, 1997.
- [281] (6/1/19). *Testing for Normality using SPSS Statistics*. Available: <https://statistics.laerd.com/spss-tutorials/testing-for-normality-using-spss-statistics.php>
- [282] P. Marr. (6/1/19). *Testing for Normality*. Available: <http://webspace.ship.edu/pgmarr/Geo441/Lectures/Lec%205%20-%20Normality%20Testing.pdf>
- [283] G. D. Hutcheson and N. Sofroniou, *The multivariate social scientist: Introductory statistics using generalized linear models*: Sage, 1999.
- [284] H. F. Kaiser, "The application of electronic computers to factor analysis," *Educational and psychological measurement*, vol. 20, pp. 141-151, 1960.
- [285] J. L. Arbuckle, "IBM SPSS Amos 24 User's Guide," ed: IBM Corporation, 2016.
- [286] J. Cohen, *Statistical Power Analysis for the Behavioral Sciences*, 2nd ed.: New York: Academic Press, 1988.
- [287] J. Cohen, "A power primer," *Psychological bulletin*, vol. 112, p. 155, 1992.
- [288] (16/3/19). *Sample Size Calculator*. Available: <http://www.raosoft.com/samplesize.html>

# Bibliography

- Blumberg, Cooper, & Schindler (2008). *Business Research Methods* (2nd European ed.): New York: McGraw-Hill Education.
- Byrne (2010). *Structural Equation Modeling With AMOS: Basic Concepts, Applications, and Programming* (Second ed.): Taylor & Francis.
- Chesbrough (2006). *Open Business Models*: Harvard Business Review Press.
- Chesbrough (2003). *Open Innovation: The New Imperative for Creating and Profiting from Technology*: Harvard Business School Press.
- Christensen, Anthony, & Roth (2013). *Seeing What's Next: Using the Theories of Innovation to Predict Industry Change*: Harvard Business Review Press.
- Christensen (1997). *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*: Harvard Business School Press.
- Christensen & Raynor (2003). *The Innovator's Solution: Creating and Sustaining Successful Growth*: Harvard Business School Press.
- Cooper (1993). *Winning at new products : accelerating the process from idea to launch* (2nd ed.). Reading, Mass.: Addison-Wesley.
- Cooper (2011). *Winning at new products : creating value through innovation* (4th ed.). New York: Basic Books.
- Cooper & Edgett (2009). *Product Innovation and Technology Strategy*: Product Development Institute.
- Creswell (2007). *Research design: Qualitative, quantitative, and mixed methods approaches*: Sage publications.
- Crotty (1998). *The foundations of social science research*: New South Wales: Allen & Unwin.
- Field (2013). *Discovering statistics using IBM SPSS statistics* (4th ed.): Sage.
- Goffin & Mitchell (2010). *Innovation Management: Strategy & Implementation Using the Pentathlon Framework* (2nd ed.): Palgrave Macmillan.
- Goldman, Nagel, & Preiss (1995). *Agile competitors and virtual organizations: strategies for enriching the customer* (Vol. 8): Van Nostrand Reinhold New York.
- Hayes & Wheelwright (1984). *Restoring our Competitive Edge: Competing through Manufacturing*: New York: John Wiley.
- Helfat, Finkelstein, Mitchell, Peteraf, Singh, Teece, & Winter (2007). *Dynamic Capabilities: Understanding Strategic Change in Organizations*: Wiley.
- Hill & Hill (2009). *Manufacturing Operations Strategy* (Third ed.): Palgrave Macmillan.
- Hill (1985). *Manufacturing Strategy: The Strategic Management of the Manufacturing Function*: Macmillan, London.
- Johnson & Scholes (1993). *Exploring Corporate Strategy* (Third ed.): Prentice Hall.
- Kahn (2012). *The PDMA Handbook of New Product Development* (3rd ed.): Wiley.
- Kim & Mauborgne (2004). *Blue Ocean Strategy: How to Create Uncontested Market Space and Make the Competition Irrelevant*: Harvard Business Review Press.

- Leonard-Barton (1995). *Wellsprings of knowledge: Building and sustaining the sources of innovation*: Harvard Business Press.
- Markides & Geroski (2004). *Fast Second: How Smart Companies Bypass Radical Innovation to Enter and Dominate New Markets*: Wiley.
- Penrose (1959). *The theory of the growth of the firm*.
- Porter (1980). *Competitive Strategy*: Free Press, New York.
- Quinn (1992). *Intelligent Enterprise: A Knowledge and Service Based Paradigm for Industry*: Free Press.
- Saunders, Lewis, & Thornhill. (2012). *Research methods for business students* (6th ed.): Pearson Education UK.
- Schwartz (1996). *The art of the long view: planning for the future in a uncertain world.*: Doubleday.
- Teece (2009). *Dynamic Capabilities and Strategic Management : Organizing for Innovation and Growth*: Oxford University Press.
- Tidd (2012). *From Knowledge Management to Strategic Competence: Assessing Technological, Market and Organisational Innovation* (J. Tidd Ed. 3rd ed.): Imperial College Press.
- Tidd & Bessant (2013). *Managing Innovation: Integrating Technological, Market and Organizational Change* (Fifth ed.): Wiley.
- Utterback (1994). *Mastering the Dynamics of Innovation*: Harvard Business School Press.