A Study of Design Innovation Framework for Innovative Manufacturing Companies in the UK

A thesis submitted for the degree of Doctor of Philosophy

by

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ABSTRACT

The importance of design to enhance innovation in businesses has gradually diversified with the expansion of the meaning and influences of design, and is now regarded as a critical strategic tool to increase commercial competitiveness and sustainable growth in a complex global market. Concurrently, the importance of embracing the extensive scope of innovation - including technological, product/service, process and organisational innovation - in businesses, especially in manufacturing companies, has been identified by scholars, industry bodies and the government as a way to avoid the 'locked-in' effect of existing technology and a business model which could hinder competitiveness. In this context, innovative manufacturing is regarded as an enabler for developing advanced and high-value manufacturing, which are considered as being of strategic importance in achieving the UK's global competitiveness and economic balance. The research, however, identified a relatively narrow view and use of design in innovative manufacturing, limiting the potential benefits of 'designing', 'design strategy' and 'corporate-level design thinking' to systematically enhance the extensive scope of innovation. The research therefore aims to create a design innovation framework to provide a comprehensive overview of design innovation actions and influences for UK innovative manufacturing companies to further improve innovativeness. The research consists of three phases: (i) the exploration phase, which explores the expanding role of design and innovation, and the context of UK innovative manufacturing, (ii) the development phase, which establishes the relationship between design and innovation in the business context, and discovering the design innovation characteristics which form the design innovation framework and its implementation process, and (iii) the evaluation phase which identifies the adaptability and usefulness of the framework in the innovative manufacturing context. Both quantitative and qualitative methods were used, including a questionnaire survey (n=48), in-depth interviews with academics and industrial experts in manufacturing and design innovation (n=36), and case-studies of UK innovative manufacturing companies (n=46). The research identified twenty design innovation characteristics with six main benefits including: (i) problem/opportunity identification, (ii) extensive collaboration, (iii) clear communication, (iv) innovative product and service development, (v) effective process development, and (vi) work culture and environment improvement. The design innovation framework and implementation process recommended by the research therefore provide a comprehensive overview of the influence of design innovation to achieve creative idea generation, optimise the business environment, and successful commercialisation which enables the improved product/service, process and organisational innovativeness of UK innovative manufacturing companies.

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1.1 Introduction

Manufacturing companies now regard design and innovation as important for increasing competitiveness and sustaining growth. Their contributory roles in business activities, developing products which add value for both businesses and customers are now acknowledged and practised by many companies. However, the expanding meaning and benefits of design through designing (activity), design strategy (managing design strategically) and corporate-level design thinking (creative business management), and innovation through technological, product/service, process and organisational innovation are not acknowledged and practised enough, to the detriment of global competitiveness in an increasingly complex market. The background to these issues will be discussed in this chapter, which identifies the research problem and rationale. The aim, objectives and research questions will be presented with an overview of the thesis. The chapter outline is shown in Figure 1.1.

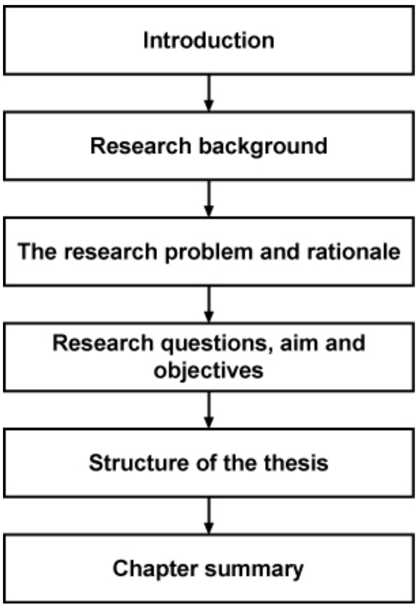


Figure 1.1: Chapter map

The initial research identified the research problem and rationale in order to formulate the aim of this research which is to create a design innovation framework that provides a comprehensive overview of design innovation actions and influences for UK innovative manufacturing companies to further improve innovativeness to enable sustained growth and increased competitiveness. The research investigates the widening areas of design and innovation for UK innovative manufacturing, to provide a holistic overview of the issues and relationships, and create theories which are applicable to UK innovative manufacturing companies and design innovation professionals.

1.2 Research background

The meaning of design in a business context has expanded over the years; it is no longer simply about enhancing aesthetics and functionalities, but has become an important factor in making business successful (Mozota, 1990, Rassam, 1995, Press and Cooper, 2003, Swann and Birke, 2005, Mozota, 2006, Valtonen, 2007, DC, 2008b, Neumeier, 2008, DC, 2012a). With this expansion, the importance of design management and 'Design thinking' has raised the issue that the design process should be seen more as a strategic business tool for increasing competitiveness by providing a holistic in-depth understanding of the market (trend identification), users (empathic research) and future direction (forecasting) which together can influence creative opportunity identification and problem-solving (Gorb, 1986, Blaich, 1988, Gemser, 1997, Trueman and Jobber, 1998, Mozota, 2002, Brown, 2009, Fraser, 2009, Martin, 2009, Banks, 2013). This change in the design paradigm has been noticed by successful business leaders and is an agenda which companies take increasingly seriously (Boland Jr. and Collopy, 2004, Sands, 2008, Lockwood, 2009, McCullagh, 2010, Rae, 2013, DC, 2014, Joziasse and Selders, 2009), regarding design as an enabler for enhanced and sustained innovation (Walsh, 1996, Bruce and Bessant, 2002a, Bertola and Teixeira, 2003, CEC, 2009, Kyffin and Gardien, 2009, Verganti, 2009, DC, 2011, DC, 2015, DTI, 2003, Tether, 2009).

The UK has for decades been a strong manufacturing nation, since the industrial revolution historically made it one of the most powerful nations globally. More recently, however, the emphasis of the UK economy has shifted towards service industries, its GVA reaching 76 per cent of GDP compared to 13 per cent in manufacturing industry (WEF, 2010). Manufacturing has steadily declined over the years, with warnings from manufacturing organisations such as the UK Engineering Employers’ Federation (EEF) forecasting that if the decline is not addressed, the entire UK economy will suffer the consequences (EEF, 2009). The importance of manufacturing industry in the UK economy is still undeniable, accounting for 50 per cent of exports with three million jobs (14 per cent of the workforce) and £152bn of output (Prest, 2008). However, with GDP growth declining in the second quarter of 2009 during the global financial crisis to as low as approximately minus six per cent (ONS, 2010), some commentators argue this may be due to the UK's over-reliance on the services industry, and that the recovery may have been slower than that of other European countries such as Germany and France (BBC, 2009). During the financial crisis, manufacturing industry was arguably the unsung hero of the UK economy, holding together the nation’s economy according to Temple (2011), who also states that as a nation the UK is finally recognising the importance of 'making things' and having a 'better-balanced' economy. The UK government consequently announced that the goal for the year 2020 is to grow UK manufacturing (BIS, 2010b) with the emphasis on advanced (BIS, 2009, BIS, 2010b), high-value (TSB, 2011c, TSB, 2012b) and innovative manufacturing (TSB, 2011b). However, the world rank of the manufacturing competitiveness of the UK is predicted to drop from 15th in 2013 to 19th by 2018 (Deloitte, 2012).

Innovation takes multiple forms: technology development, commercialisation and organisational culture (Utterback, 1986, West and Anderson, 1996, Peters, 1997, Cumming, 1998, Boer and During, 2000, Kelly, 2001, Tidd et al., 2005, Fagerberg, 2006, Keeley et al., 2013) in almost all social-economic areas (Baregheh et al., 2009). It is still one of the top agenda items for top-level managers in companies around the world (BCG, 2014, PWC, 2014) where its performance is regarded as determining a company’s success (Tucker, 2001, DTI, 2006, Hansen and Birkinshaw, 2007, Love et al., 2009, Jolly, 2010, PWC, 2013a). The importance of innovation in manufacturing companies is also apparent from academic, industry and government perspectives (Moody, 2001, ReVelle, 2002, Trott, 2005, Guan et al., 2006, Laforet and Tann, 2006, Sainsbury, 2007, BERR, 2008, BIS, 2011a, TSB, 2011b, EEF, 2014).

1.3 The research problem and rationale

Manufacturing in the UK is considered important by the UK government and industry, where innovation is acknowledged as a key to increase competitiveness and ensure prolonged growth for businesses. Innovative manufacturing has great value for developing manufacturing industry and the UK economy as whole, and the wider spectrum of design is recognised as an essential link between creativity and innovation, where expanding the use of design at the operational (the action of designing products/services), strategic (the methodological process), and corporate (the philosophical principle) levels of business is becoming an important agenda for globally successful companies. Despite the interlinking relationships between design, innovation and manufacturing development, the wider spectrum of design is sparsely used in UK manufacturing companies despite UK having one of the most advanced creative industry in the world (Cox, 2005). The limited use of design even at operational level is examined in two studies by the Design Council (2007) and Livesey and Moultrie (2009). By the nature of the manufacturing industry, design is used more than in any other sector, but the studies show that the use of design is overwhelmingly in technical design for manufacturing companies, compared with other sectors such as retail, finance and service, which use different types of design more widely. However obvious this may seem, it contributes towards the manufacturing industry underutilising design with a steady level of creative sector GVA (approximately ten per cent) between 1992 to 2003, where during the same period the service industry increased its creative sector GVA from forty per cent to approximately ninety per cent (Cox, 2005).

Governmental and non-governmental support is available to companies to use the wider spectrum of design. Among the more systematic support is The Design Council’s Designing Demand, which manifests the value of design by helping companies at different levels of design maturity with mentorship from Design Associates (DC, 2010). Innovate UK (formerly the Technology Strategy Board or TSB) on behalf of the UK government supports manufacturing companies similarly with Design Options (TSB, 2012a), using the design mentor approach to help a business identify the commercial value of their R&D efforts. A more active interest in using the broader design spectrum in manufacturing is led by The Design Council (DC, 2014, DC, 2015); the main agenda for the 2015 Design Council Summit was design and manufacturing in the UK. However, there is greater emphasis in manufacturing industry on innovation (PWC, 2013c, Coad et al., 2014, EEF, 2014) where it is much more widely mentioned in the manufacturing sector than design. Despite this recognition, the limited use of broader spectrum innovation - including product, process, marketing and organisation (OECD, 2005, Teece, 2010, Keeley et al., 2013) - is also apparent in manufacturing companies where NESTA warns that not using "hidden innovation" to achieve "Total Innovation" could be a pivotal disadvantage to achieving sustained global competiveness in the complex global market by being "locked-in" to existing technologies and business models (NESTA, 2008b). This limited perspective of innovation also applies to innovative manufacturing, where the focus is predominantly on technological and product innovation (Mosey et al., 2002, Laforet and Tann, 2006). Expanding the use of innovation towards Total Innovation is therefore an important agenda for UK innovative manufacturing companies to increase their global competitiveness.

Promoting the value of design to encourage the use of the broader spectrum of design occurs in two ways: firstly, by demonstrating the financial benefit of design (DC, 2004, DC, 2012a, Rae, 2013), and secondly, by using a comprehensive overview to show the benefits (Cooper and Press, 1995, Best, 2006, Mozota, 2006, Bruce and Bessant, 2002a, DC, 2011). Providing information about the financial benefits of design can be highly effective, especially for top-level managers to appreciate the value of design for company growth. However, the limitation is that design has to have distinctive boundaries within the company, i.e. design spend must be defined as an exact proportion of Return of Investment (ROI) for design, which can be difficult to define. Encouraging the use of design by providing information on the expanding spectrum of design and its effects on businesses can provide a vital opportunity for companies to consider design when seeking to increase their competitiveness. However, this depends heavily on the perception of design and the willingness of top-level management to accept design as important for their company (DC, 2014). This is where innovation becomes important. As already explained, manufacturing companies - particularly innovative manufacturing companies – regard innovation as important, and although it is usually limited to technological innovation, more active conversations take place, so innovation is more highly accepted than design. Therefore, demonstrating the influences of design for innovation achieves better implementation of design through a better understanding and acceptance of the broader design spectrum.

Despite this opportunity, limited empirical research has been done to provide a comprehensive overview of design and its effects on improving different types of innovation in the context of innovative manufacturing companies. The relationship between design and innovation can be found in several literatures, rather, it is harder to find a text which does not associate design with innovation. However, depending on the focus of the research, either design or innovation is generalised or marginalised (Cumming, 1998, Freel, 2000, OECD, 2005, Gemser et al., 2011, Visser, 2009), which can cause confusion for companies which seeks to improve a particular type (area) of innovation but with limited knowledge of the broader design spectrum. This can also lead to increased "fuzziness" of the importance of design for innovation, which is particularly problematic for convincing the innovative manufacturing companies about the extensive benefits of design to increase innovativeness. Hence "providing formal framework for design reasoning has become a vital issue, which goes well beyond academic circles as industrialists are also voicing their concerns" (Le Masson et al., 2010:63). Developing a framework which provides a comprehensive overview of the wider spectrum of design and its influences on different types of innovation is therefore timely and important.

This research therefore considers both theoretical knowledge creation and the practical application of the theory, which has the potential to benefit: (i) the academic discipline of design, innovation and manufacturing management by enhancing the understanding of design's beneficial influence on innovation for the UK innovative manufacturing context, (ii) innovative manufacturing companies, including their top-level managers and design or innovation managers, by providing a framework and its implementation process, with a comprehensive overview of design innovation, its actions, effects and benefits which can be applied to enhance their innovativeness, and (iii) design innovation support organisations (governmental and non-governmental organisations and commercial design innovation consultancies), by providing a systematic schematics of design innovation areas empirically proven to nurture innovation, which can be used to convince innovative manufacturing companies to utilise design more extensively to achieve Total-innovation.

Through these benefits, manufacturing industry can grow in the complex global market, thereby increasing the overall competitiveness of the nation.

1.4 Research questions, aim and objectives

Background research and further literature reviews (Chapter 2) were conducted to understand the research context (design, innovation and manufacturing), and identified the following research questions:

(Q1) What are the perception and utilisation of design in UK innovative manufacturing companies?

(Q2) What are the design innovation influences that enable UK innovative manufacturing companies to further increase their innovativeness?

(Q3) How can innovative manufacturing companies implement design innovation and embrace the benefits to improve business performance?

The research aims to create a design innovation framework to provide a comprehensive overview of design innovation actions and influences for UK innovative manufacturing companies to further improve innovativeness which enables sustained growth and increased competitiveness. Design Innovation is here defined as a creative process with the outcome of enabling increased innovativeness in a company by using the full design spectrum, including designing (action to create products/services), design strategy (management of the design process), and corporate-level design thinking (the philosophy and method of design applied in managing a business holistically). The outcome of design innovation can thus be radical and/or incremental changes in product, service, process, organisational culture, and/or the business model. An Innovative Manufacturing Company is defined as a commercial organisation in the manufacturing sector which recognises the importance of innovation by (i) continuously introducing new or improved products/services, (ii) improving production processes, (iii) actively seeking new markets, (iv) collaborating with external organisations such as universities, (v) improving ways of working, and/or (vi) winning innovation prize(s). The research identified that innovative manufacturing is an enabler for advanced manufacturing to expand into high-value manufacturing, and a catalyst for other manufacturing companies to increase their competitiveness in the global market (see Chapter 2 and Chapter 4). Therefore scope of the research includes design, innovation and manufacturing, providing overview of each areas and bringing together the theories and practical knowledge through the design innovation framework (see Figure 1.2). In order to answer the research questions and fulfil the aim of the research, the following objectives were constructed:

(OB1) To review existing theories about the use of design and innovation in businesses, to understand the scope of the relationship between design and innovation

(OB2) To investigate UK manufacturing's contribution to the UK economy and national competitiveness and establish a definition of UK innovative manufacturing, and its relationship with advanced and high-value manufacturing, to identify their strategic importance

(OB3) To investigate UK innovative manufacturing companies' current perception and utilisation of design, in order to understand the issues surrounding design

(OB4) To identify the relationship between design and innovation by creating and evaluating a design innovation spectrum, which is an overview of design innovation in innovative manufacturing companies

(OB5) To identify design innovation characteristics containing actions and the benefits of design innovation for UK innovative manufacturing companies

(OB6) To create and evaluate a design innovation framework, including an implementation process for UK innovative manufacturing companies to further increase innovativeness and encourage business growth.

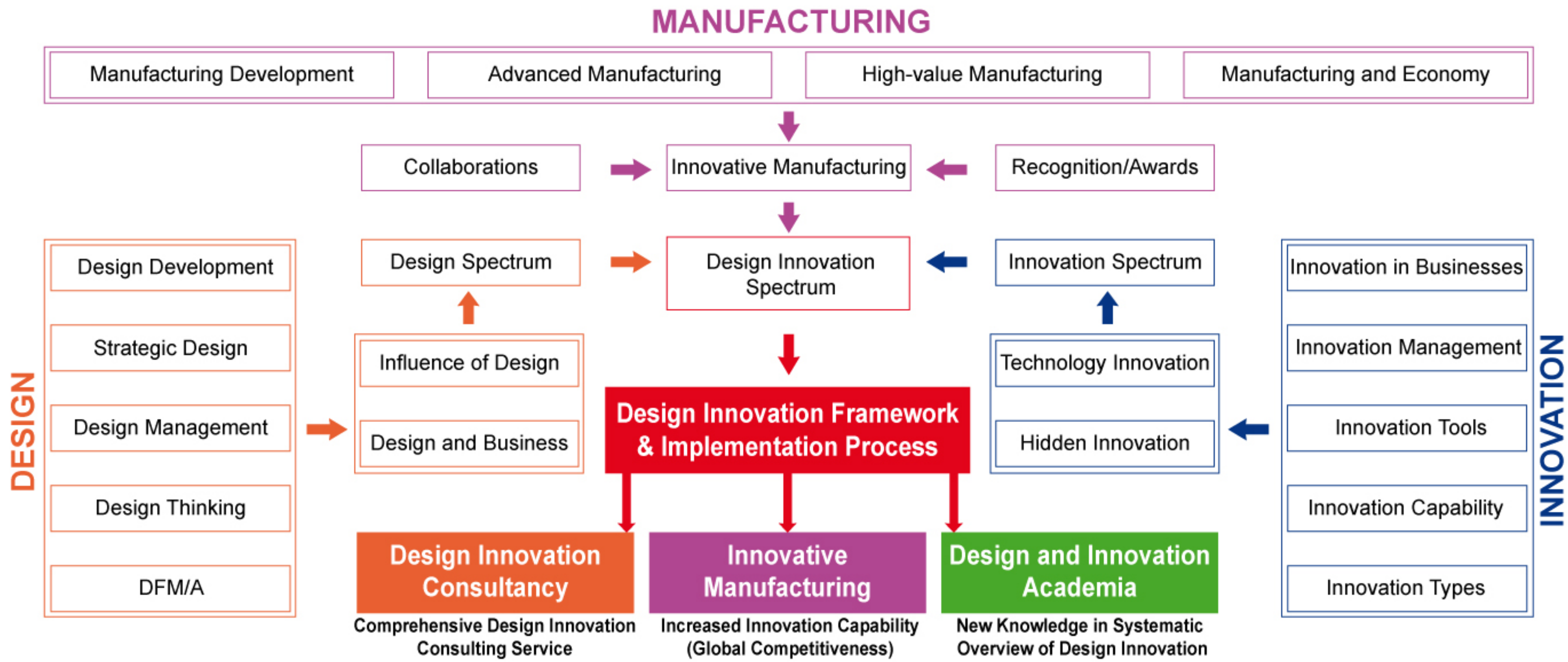


Figure 1.2: Scope of the research

1.5 Structure of the thesis

The thesis comprises eight chapters which describe the research journey undertaken to construct the design innovation framework and its implementation process. Overview of structure for the thesis is shown in Figure 1.3 with further details explained in this section.

Chapter 1 is an overview of the research, using background research to identify the problems and the apparent lack of studies comprehensively exploring current design and innovation trends, and their extensive benefits to innovative manufacturing. The research questions arose from background research and the literature review of current theories, seeking answers about the research gaps in: (i) the perception and utilisation of design in innovative manufacturing, (ii) the relationship between expanding areas of design in extensive areas of innovation, (iii) design innovation characteristics and their influence on innovative manufacturing companies to increase innovativeness, and (iv) an appropriate implementation process to embrace expanding areas of design innovation. The research rationale and aim were created and the subsequent formulation of the objectives to achieve the aim.

Chapter 2 comprises the literature review results, and a discussion about the fundamentals of design and innovation, acknowledging the complexity of their meaning and the expanding parameters of both design and innovation. Theories about the relationship between design and innovation are also discussed, eventually defining the term 'design innovation' for this research: a creative process and its outcome which enable increased innovativeness of a company by using the full design spectrum, including designing (action to create a product), design strategy (management of the design process), and corporate-level design thinking (the philosophy and method of design applied to business management). Chapter 2 also discusses the importance of UK manufacturing, which is regarded as key to a stable balanced UK economy. In order to develop competitive manufacturing in the complex global market, advanced, high-value and innovative manufacturing are identified as strategically important. Among the different types of manufacturing, innovative manufacturing seeks to provide the balance between efficiency and innovation, yet the apparent absence of any extensive use of design is also identified and discussed in this chapter.

Chapter 3 explains the methodological approach of the research, and discusses theoretical descriptions of epistemology, theoretical perspectives and the various research methods which were adopted. The research uses constructivist epistemology with an interpretivist theoretical perspective with an inductive approach to conducting explorative research. This approach, adopted because the research deals with complex objects (design innovation and innovative manufacturing), seeks to provide both theoretical and practical answers to the enquiry by creating a design innovation framework and its implementation process to find the meaning to further improving innovativeness in UK innovative manufacturing companies. The formulation of the research strategy is followed by a discussion of the research design which includes exploration, development and evaluation phases. The chapter therefore provides justifications, sampling and analysis techniques of the exploratory interview, questionnaire survey, in-depth interviews and case-study methods. The research uses both qualitative and quantitative methods to increase the reliability of the research. The research is also designed to increase validity by continually evaluating the research outcomes. The reliability, validity and research ethics are also further discussed in this chapter.

Chapter 4 discusses the exploratory phase of the research with findings from the exploratory questionnaire and interviews to provide an overview of innovative manufacturing. A contextual model of UK innovative manufacturing is created in this chapter, firstly to identify the relationship with advanced and high-value manufacturing, and secondly to extend the meaning to show the relationship with various types of innovation and integrated business values. A discussion follows about the perception, role and utilisation of design in UK innovative manufacturing, which identified the paradox that innovative manufacturing companies understand the importance of design but have a limited understanding of design’s extensive benefits. The discussion continues with examples from the in-depth interviews with manufacturing experts, which also addresses the apparent lack of awareness of the benefits of design.

Chapter 5 presents the development of the design innovation spectrum, which was constructed by combining the design spectrum - *designing, design strategy and corporate-level design thinking* - with the innovation spectrum - *technological*, *product/service,* *process and organisational innovation*. The theories relating design and innovation in the commercial environment are analysed to create an initial spectrum, which was then evaluated using a series of in-depth interviews with design innovation experts, including top-level managers of design innovation consultancies and senior managers in design and manufacturing support organisations. The interview findings provided a practical evaluation of the design innovation spectrum which resulted in the creation of design innovation spectrum that is both theoretically and practically comprehensive. The case-study findings are then discussed, placing the spectrum in real-life situations in UK innovative manufacturing companies.

Chapter 6 identifies the design innovation characteristics - including design innovation actions, effects and benefits for innovative manufacturing companies - through analysis of in-depth interviews with design innovation and manufacturing experts and the literature review. Twenty characteristics were identified: technology utilisation, quality improvement, computer aided design (CAD), technical design, aesthetics, function/usability, product/service value promotion, graphics/website, user need/demand, market need/demand, feasibility testing (prototyping), knowledge capture/transfer (KM), external collaboration, internal collaboration, top-level management support, physical work environment, investment, company vision/values, the unique selling proposition (USP) and the business model. These characteristics were then placed in the design innovation spectrum to provide a positional overview in a business context.

Chapter 7 discusses the construction of the design innovation framework and its recommended implementation process. The twenty design innovation characteristics were further categorised into six benefits of design innovation: problem/opportunity identification, extensive collaboration, work culture/environment improvement, efficient process development, clear communication, and innovative product/service development. The main goals of design innovation identified through further analysis include: creative idea generation, optimising the business environment, and successful commercialisation. The discussion continues with the findings from evaluation interviews with design innovation and manufacturing experts, to finally recommend a design innovation framework and implementation process which will enhance the innovativeness of UK innovative manufacturing companies.

Chapter 8 concludes the research by reviewing the key research findings against the aim and objectives. Theoretical and practical research contributions are discussed, acknowledging the research limitations of the topic, data collection and analysis, and validation. Recommendations were made on this basis for further research in this chapter.

1.6 Chapter summary

This chapter has provided the background to the research and identified the research problem and the subsequent research rationale. The importance of UK manufacturing development is briefly explained, with innovation considered as a key to achieve global competitiveness and prolonged growth. The scarcity of empirical research about this context, which individually relates to each different area of design and innovation, is identified - which may be a key to ensuring better adoption of design at all levels of business to further enhance the innovativeness of UK innovative manufacturing companies. The aim, objectives and research questions were presented with an overview of the thesis structure.

The next chapter presents an in-depth review of literatures in design and innovation that identifies the expanding role and parameters of design and innovation, their relationship. The importance of manufacturing with particular focus on innovative manufacturing for the UK is also discussed in the Chapter 2.

Chapter 1	Chapter 2	Chapter 3	Chapter 4	Chapter 5	Chapter 6	Chapter 7	Chapter 8
Introduction:	**Literature Review:**	**Research Methodology:**	**Design in UK Innovative Manufacturing:**	**Design Innovation Spectrum:**	**Design Innovation Characteristics:**	**Discussion and Recommenda-tions:**	**Conclusion:**
• Overview of research • Research background • Research problems and rationale • Aim and objectives • Structure of thesis	• Fundamentals and expanding parameters of design and innovation • Relationship between design and innovation • Importance of manufacturing for the UK • Description of innovative manufacturing	• Research strategy in epistemology and theoretical perspectives • Research design with mixed methods • Sampling and data analysis • Reliability and validity	• Overview of innovative manufacturing • Perception, role and utilisation of design in UK innovative manufacturing	• Development of design spectrum and innovation spectrum • Creation of design innovation spectrum with evaluation through in-depth interviews • Case studies in relation to design innovation spectrum	• Design innovation actions and effects • Design innovation characteristic identification through in-depth interviews • Convergence with design innovation spectrum	• Design innovation framework development • Framework implementation process formulation • Evaluation interview findings	• Overview of the research findings • Limitation of the research • Recommendation of further research
Research Context and Methodology			**Exploratory Phase**	**Development Phase**		**Evaluation Phase**	**Research Conclusion**

Figure 1.3 Structure of the thesis

CHAPTER 2. Literature Review

2.1 Introduction

The meanings of design and innovation vary greatly depending on the individuals, background knowledge and experiences involved. Both are large complex topics which elicit diverse theories and opinions from both academics and practitioners. It is therefore important to establish the meanings of design and innovation adopted for this research, to provide a clear understanding of their roles, implications and capabilities. An overview of the topics discussed in this chapter is shown in Figure 2.1. The first two sections discuss theories of design and innovation separately, deconstructing each to enable a better understanding of the elements of the constructs and expanding parameters of design and innovation. Design here includes designing, design strategy and corporate-level design thinking, while innovation includes technological, product/service, process and organisational innovations. A discussion then follows of the relationship between design and innovation where 'Design Innovation' for this research is defined as a creative process with the outcome of enabling increased innovativeness in a company by using the full design spectrum, including designing (actions to create products/services), design strategy (management of the design process), and corporate-level design thinking (the philosophy and method of design applied in holistic business management).

This is followed by a literature review of UK manufacturing, to identify its importance in the national economy. High-value, advanced and innovative manufacturing are identified as strategically important for developing UK manufacturing competitiveness. The relationship between the three types of manufacturing is discussed with reference to the literatures. The theory of innovation and manufacturing is studied in greater depth, identifying the indicators of innovative manufacturing companies as commercial organisations in the manufacturing sector, recognising the importance of innovation by (i) continuously introducing new or improved products/services, (ii) improving production processes, (iii) actively seeking new markets, (iv) collaborating with external organisations such as universities, (v) improving working practices, and/or (vi) winning innovation prize(s).

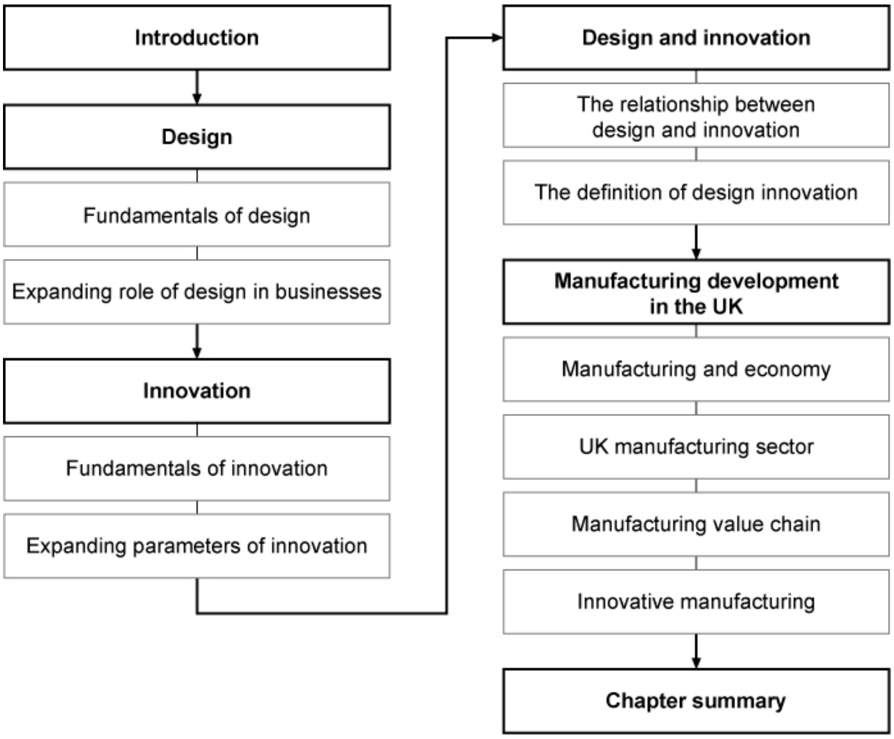


Figure 2.1: Chapter map

2.2 Design

The definition and scope of design have been debated from many perspectives throughout history (Visser, 2009, Erichsen and Christensen, 2013). These diverse areas and concepts have made it difficult for both non-designers and designers alike to grasp a clear meaning of design (Trueman and Jobber, 1998, Mozota, 2003). Table 2.1 illustrates this point by describing the work of design from four perspectives in a commercial environment, with various meanings and expectations depending on the different viewpoints (Roy, 1994, Walsh, 1996). The definition of design also changes according to the context in which it is used, so design is a highly fluid concept, almost impossible to pin down with a definitive description (Tether, 2005).

Table 2.1: Various perspectives of the work of design in a firm

Designers	Managers	Consumers	Strategic Management
• creativity • problem-solving • art • technical performance • ergonomics	• product differentiation from competitors • making people want to buy, even in a recession • a product's commercial impact	• creation of new styles fashions and images • product improvement: easier to use, longer lasting or energy-saving • value for money	• adding value to business, • increasing production • efficiency in the use of materials and energy • generating increased profits

Source: Adapted from (Roy, 1994, Walsh, 1996)

This section discusses the fundamentals of design, including its disciplines, its relationship with creativity, the actors and process, together with a deconstruction of design to better understand its elements in a business context.

2.2.1 Fundamentals of design

The word 'design' is both a noun and a verb (Bruce and Bessant, 2002b, BSI, 2008, Cooper and Junginger, 2009). The noun often refers to both tangible and intangible artificial outputs created by specific design disciplines: engineering design, product design, fashion design, graphic design, and service design etc., (Cooper and Press, 1995, Bruce and Bessant, 2002b, Best, 2006). The verb 'design' usually describes a cognitive activity which improves a situation (Simon, 1996, Verganti, 2009, Visser, 2009). It is also described by a C-K theory where C represents concepts and K describes knowledge, where design is a systematic expansion of concept simultaneously using and creating knowledge at the same time (Hatchuel and Weil, 2003, Le Masson et al., 2010). BIS (2010a) describes the six essential characteristics of design as: (i) multi-faceted, (ii) a link from creativity to innovation, (iii) offering competitive distinction, (iv) planning and problem-solving, (v) progressing from chaos to order, and (vi) system thinking. Visser (2009) also characterised design as a cognitive approach, describing design as (i) a cognitive activity, (ii) a problem-solving activity which includes problem-structuring and problem-solving, (iii) an activity which deals with ill-defined ('wicked') problems which can rarely be broken down into sub-problems yet have multiple possible solutions rather than one 'correct' solution, (iv) a 'satisficing' activity which seeks all possible solutions and chooses the best solution, (v) an activity which generates an initial solution kernel in the early stages of a project by setting a few simple objectives, (vi) an activity whose problems and solutions have no preexisting criteria to conduct objective evaluation where designers' tacit knowledge is referred to in tandem with technical criteria to agree a best solution, (vii) an activity which re-uses knowledge from previous projects, and (viii) an activity which is often opportunistically organised, making it non-systematic and multidirectional. These characteristics reinforce the concept of design as a problem-solving, creative, systematic and co-ordinating activity (Mozota, 2003) which links creativity and innovation (Cox, 2005). The meaning of design for UK businesses was surveyed with 1,500 UK firms by PACEC for The Design Council. The overwhelming majority regarded design as a tool to "develop new products and services" (75%) and "how products look" (74%) as shown in Figure 2.2, predominantly focusing design on its outcome but not as "a strategic business tool" (34%), about which businesses were least able to agree (Tether, 2005).

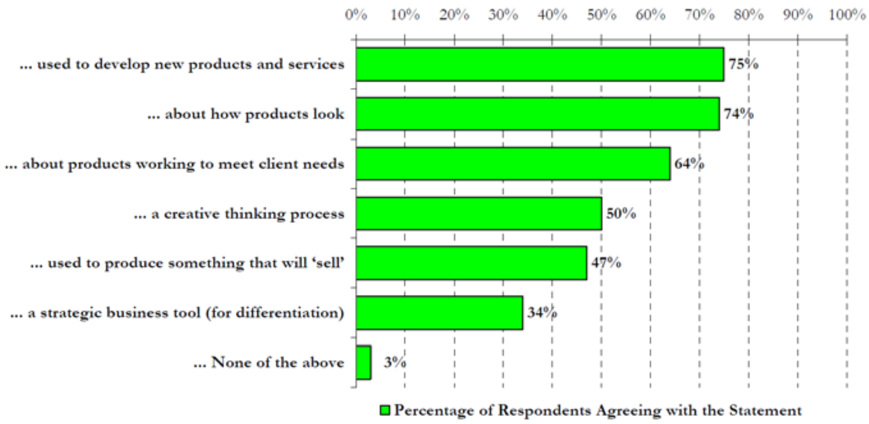


Figure 2.2: The meaning of design for UK businesses (Tether, 2005:2)

This thesis, however, adopts a holistic view of design, defining design as:

'a multi-faceted cognitive process and its practical outcome which identify and create optimum solutions to problems by linking creativity and innovation.'

2.2.1.1 Design disciplines

David Walker's Design Tree Diagram (Figure 2.3,(Cooper and Press, 1995) describes the historic root of the various design principles, representing a realm of design in both art and science which stems from the craft roots. Von Stamm (2008) describes diversity in design as an evolution which resulted from the Industrial Revolution where work specialisation required the separation of design into ‘design as art’ and ‘design as engineering’ (von Stamm, 2008).

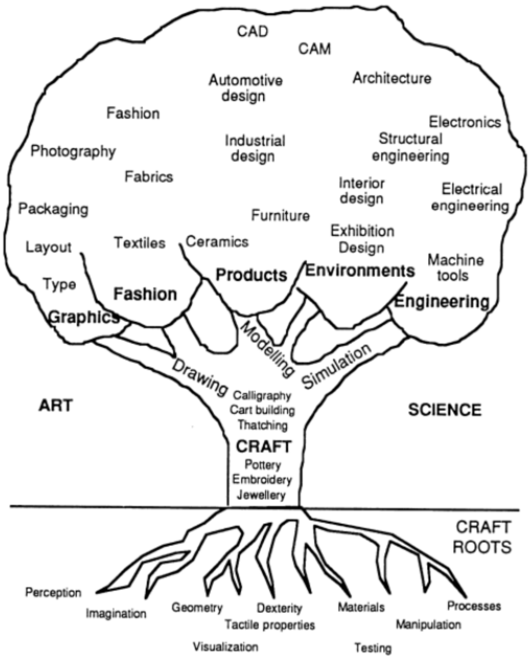


Figure 2.3: Design tree diagram (Cooper and Press, 1995:27)

Von Stamm quotes Ivor Owen, former Director of The Design Council, describing a darker side to this evolution where the separation between engineering design (design as engineering) and industrial design (design as art) is damaging in manufacturing industry as almost all products need a balance of both. However, design diversification becomes more apparent as more design disciplines are added to accommodate changing market demands such as web-design, interaction/interface design, service design, etc., not listed in the Design Tree but now universally regarded as design disciplines. Design disciplines are distinguished by their outcome, so design is seen as an activity to reach a specific outcome set by the stakeholder, whether commercial or non-commercial (DC, 2007, Press and Cooper, 2003).

2.2.1.2 Design and creativity

Creativity is one of design’s most important traits, described by Bruce and Bessant (2002b) as an “engine behind design”. Their definition of creativity as “the ability to combine ideas in new ways to solve problems and exploit opportunities” (Bruce and Bessant, 2002b:32) is particularly relevant in a business context, where generating ideas fulfils all aspects of a particular business purpose, from designing a new product/service, to production, marketing and distribution (DTI, 2005). Creativity is thus not limited in a company to activities which help develop a new product or service. This is further demonstrated by the Institution for Business Value survey of 1,500 CEOs which identified 'creativity' as the most important leadership competency for the successful enterprise, which brings the importance of being creative to top-level business management (Businessweek, 2010).

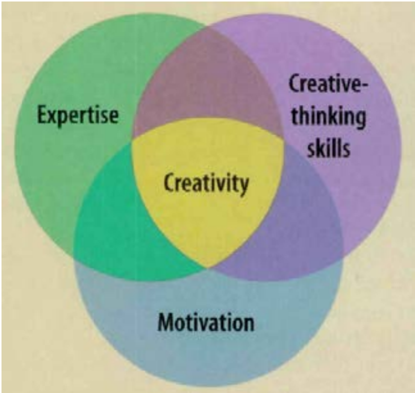


Figure 2.4: The three components of creativity (Amabile, 1998:78)

Amabile (1998) and Kelly and Kelly (2013) also cite creativity as essential to business success, emphasising that it should be encouraged and practiced in businesses. According to Swann and Birke (2005), the characteristics of creativity includes bisociation, autonomy and incubation. Similarly, Amabile (1998) identifies three components of creativity: expertise, creative thinking skills and motivation (see Figure 2.4) which function together to enable creativity. Creative traits are explored in more detail by von Stamm (2008) who lists thirty-two creative traits, relating them to designers' traits (see Figure 2.5), showing remarkable similarities.

Sensitive	**Question asker**	**Ingenious**	**Curious**
Not motivated by money	**Can synthesise**	**Energetic**	**Open-ended**
Sense of destiny	**Able to fantasise**	Sense of humour	**Independent**
Adaptable	**Flexible**	Self-actualising	**Severely critical**
Tolerant of ambiguity	**Fluent**	Self-disciplined	**Non-conforming**
Observant	**Imaginative**	Self-knowledgeable	**Confident**
Perceive the world differently	**Intuitive**	**Specific interests**	**Risk-taker**
Sees possibilities	**Original**	**Divergent thinker**	**Persistent**

Figure 2.5: Creative traits - with designers' traits in bold (von Stamm, 2008:21)

The relationship between creativity and design is clearly evident from the similarities of their various traits. Design is thus regarded as a principle which can be applied to business management (Boland Jr. and Collopy, 2004, Martin, 2009). However, there is constant - often unintentional - tension between creativity and business imperatives or the need for stability and efficiency. This can be a hindrance when using design to develop a creative culture for a company, which may reduce the chance of increasing the company's competitiveness (Amabile, 1998, Trott, 2005).

2.2.1.3 Designers and design professionals

The question "who are the designers?" is also complex because of the fluid meaning of design, depending on the context in which the word is used. In an attempt to simplify the meaning of design, the BIS (2010a) states that "design is what designers do". Papanek (1985) also suggests that everyone is a designer because design is fundamental to all human activity. However, in a commercial context, this broad definition of 'designers' can cause confusion. In this context, a designer is usually classified as someone who has educational and/or commercial experience of one of the design disciplines described earlier. Design and market orientation are distinct but both are necessary to be successful in the market (Moll et al., 2007). The comparison between design thinking and business strategy (Liedtka, 2010) in Table 2.2 shows the conflict of interest between design and business where design tends to focus on creativity, emotions and pursuit of novelty, yet the business focuses on logic, rationale and stability.

Table 2.2: Comparison of design and business strategy

	Design	**Business**
Underlying Assumptions	Subjective experience; reality as socially constructed	Rationality, objectivity; reality as fixed and quantifiable
Method	Experimentation aimed at iterating towards a "better" answer	Analysis aimed at proving one "best" answer
Process	Doing	Planning
Decision Drivers	Emotion; experiential models	Logic; numeric models
Values	Pursuit of novelty; dislike of status quo	Pursuit of control and stability; discomfort with uncertainty
Level of Focus	Movement between abstract and particular	Abstract or particular

Source: (Liedtka, 2010:9)

Walker (1990) and McCullagh (2006) further compared the difference between designers and managers (strategists), arguing that designers are likely to be creative problem-solvers compared to business strategists and managers who are more analytic, logic-driven problem-solvers. Moreover, designers tend to be empathic towards the user, whereas managers and business tend to focus more on the company's difficulties and challenges. However, in reality it is less distinctive than the authors describe, where the design activity and design decisions in a firm involve characteristics of both designers and non-designers e.g. engineers, programmers and managers (von Stamm, 2008). The question "who are the designers?" is thus paradoxical in this context. Gorb and Dumas (1987) introduced the 'silent designer' in a firm, who has important design decision-making responsibilities without any design training. This research views design holistically, so adopts the 'silent design' theory. To avoid confusion, the practitioners who are trained in design disciplines will be termed 'design professionals', so the term 'designers' will be used to describe both the design professionals and the silent designers who make a significant contribution in design decisions. The term 'design thinkers' will also be used to describe the people in a firm who use design principles and methodology in areas other than designing products/services.

2.2.2 Expanding role of design in businesses

The significance of design in the business context has recently expanded and is no longer simply about enhancing aesthetics and functionalities: design has become an important factor in making business successful (Mozota, 1990, Press and Cooper, 2003, Valtonen, 2007), because design has a prominent role in all origination and manufacturing processes (Howkins, 2002). The Design Council consistently conveys the message that design benefits business performance because businesses which invest in design increase their revenue twentyfold, net operating profit fourfold, and export fivefold (DC, 2012a). Another Design Council study measuring the relationship between the effective use of design and share price performance (DC, 2004) shows that design-led companies outperformed FTSE 100 and FTSE All Share indices by more than 200 per cent between December 1993 and December 2004. Hertenstein et al. also provide evidence of design effectiveness on company financial performance (Hertenstein and Platt, 2001, Hertenstein et al., 2005) The argument that design is good for business is based on a good design being a source of competitive advantage, avoiding competing on price alone by: (i) creating new products and services, (ii) adding value through innovation, (iii) stimulating exports, and (iv) attracting investment and identifying markets (DC, 2008b). Numerous other literatures describe the benefits of design; Trueman and Jobber (1998) describe design attributes in business, dividing the design dimension into four groups: value, image, process and production (Table 2.3). The design dimensions are associated with particular company goals, showing how design benefits many areas of design, not just company performance but also in the areas of culture (process) and efficiency (production). Furthermore Joziasse and Selders (2009) describe design's added value in terms of speed of change in both the company and society.

Table 2.3: Design dimensions and attributes against company goals

Design Dimensions	Design Attributes	Company Goals
Value	Product Styling, Aesthetics Quality Standards Added Value	To add value for the consumer and enhance a company's reputation
Image	Product Differentiation Product Diversification Product Identity Brand Identity Brand Creation	Company image and strategy
Process	Generating New Ideas Idea Communication Interpreting Ideas Integrating Ideas Promoting Products	Culture for new ideas, creativity and innovation
Production	Reducing Complexity Using New Technology/Materials Reducing Production Time	Improvement and reduced time to market

Source: Adapted from Trueman and Jobber (1998)

Mozota (2006) uses the Balanced Score Card (BSC), the vision-based business strategy tool widely adopted by business managers, applying four key questions from the BSC to emphasise the 'four powers of design' for businesses: (i) design as difference, (ii) design as performance, (iii) design as vision, and (iv) design as contributor to financial success. These added values design brings to businesses has led design to become an important strategic tool for businesses to increase competitiveness (Kotler and Rath, 1984, Mozota, 1990, Trueman and Jobber, 1998, Larson et al., 2007, Liedtka, 2010). Topalian (2013) also provides insight about design's contribution as a strategic resource:

- design as a discipline in design and other activities
- design professionals in relation to design matters, undertaken in design projects and other activities
- design professionals in non-design matters, sometimes leading through design
- clients (and sponsors) who are ultimately responsible for the outcomes of design initiatives, and often have greater influence on the quality of solutions than the creative specialists involved.

The expanding role of design and its meaning in businesses have raised the importance of design management and 'Design thinking' where its creative processes, methods and philosophy are recognised as an appropriate resource to enable enhanced and prolonged innovation for businesses (Brown, 2009, Martin, 2009, Clark and Smith, 2008, Carr et al., 2010, Best, 2011, Liedtka and Ogilvie, 2012, Venkatesh et al., 2012, Mootee, 2013). This change in the design paradigm has been noticed by business leaders Apple, Dyson and Burberry (DC, 2011) and has become an increasingly serious agenda for companies (McCullagh, 2010), taking a more prominent role in a company rather than remaining hidden behind other company functions (Figure 2.6).

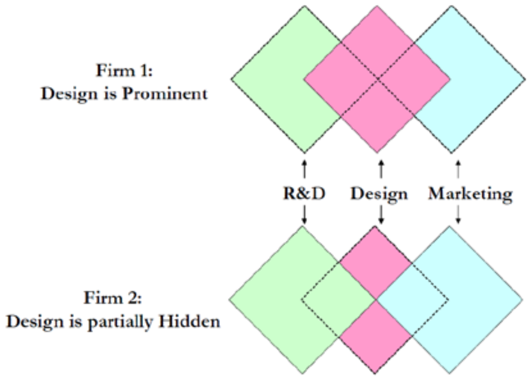


Figure 2.6: Different perspectives on the importance of design (Tether, 2005:6)

The Design Management Institute (DMI) has produced research on performance in fourteen US 'design conscious' companies: Apple, Coca-Cola, Ford, Herman-Miller, IBM, Intuit, Newell-Rubbermaid, Nike, Procter & Gamble, Starbucks, Starwood, Steelcase, Target, Walt Disney and Whirlpool (Rae, 2013). The selection criteria for the companies include: (i) publicly traded in the US for more than ten years, (ii) design is an integrated function and organisation catalyst for change, (iii) increase in design-related investments and influence, (iv) design is embedded in the organisational structure, (v) presence of design leadership at senior and divisional levels, and (vi) senior-level commitment to use design as an innovation resource for positive change. The study indicates that those companies grew 299 per cent compared to S&P's 75 per cent growth from 2003 to 2013. The result reflects The Design Council's study on design and company performance mentioned earlier (DC, 2012a).

Table 2.4: Design values for design-conscious companies in the USA

Design Values	Descriptions (Results)	Cases
The wow factor	Aesthetically pleasing, more compelling to use, and more relevant in the world	Tesla, Apple
	Consumers' support over time by differentiating with design	Target (Tar-zhay)
Brand expression	Consumers feel a personal connection with brands as an extension of themselves - establishing dialogue	Nike
Solving unmet user needs	First-mover advantage by understanding the end-user through empathy- helps reveal inspiration for category-killing products and lowers the risk of failure	Intuit (internal program based on design thinking to better understand customers' frustration)
Developing better customer experiences	Seamless, branded and differentiated experience to meet customers' functional and emotional needs	Disney (park and resort unit)
Rethinking strategy	Use of design tools (empathy, creativity, rationality) to mucky complex issues which are hard to solve - Design thinking	IBM (utilisation of Designcamp, one-week design-thinking training by product managers, developers and designers)
Hardware/software/service integration	Saves time, more productive and provides emotional support for consumers through well-crafted interaction to provide a delightful experience	Coca-cola (Freestyle-fountain drink machine)
Market expansion through persona development and user understanding	Helps companies assimilate requirements to capture hearts and minds of a new type of customer by understanding and interpreting people and cultures – a wider variety of customers and long-term loyalty	Aloft (fills an unmet desire in younger travellers)
Cost reduction	Rethinking ways and means products come together for manufactured goods	Procter & Gamble (process to develop thinner, cheaper, more environmentally friendly plastics)

Source: Adapted from Rae (2013)

This study also includes the eight design values these companies employ to maintain competitiveness (Table 2.4) which shows that successful companies are adopting design to understand and empathise with users to fulfil their conscious or unconscious needs and build relationships with them. Design-thinking is also being used as a tool to create competitive strategic advantages.

The research found that the effect of design has broadly two aspects: i) influencing the actual production and delivery of the product/service, and ii) influencing the management of a company. These two design effects have three key elements describing design: (i) designing (production, process and image), (ii) design strategy (managing design), and (iii) corporate-level design thinking (managing the company). The key literatures to formally identify these three areas are show in Table 2.5.

Table 2.5: Key literatures and the areas of design spectrum

Areas of design	Key literatures
Designing (Production/Product)	(Dumas and Whitfield, 1989, Lindbeck, 1995, Rassam, 1995, Trueman and Jobber, 1998, Poli, 2001, Bertola and Teixeira, 2003, Mozota, 2003, Press and Cooper, 2003, DTI, 2005, Tether, 2005, Best, 2006, McCullagh, 2006, Mozota, 2006, BSI, 2008, DC, 2008a, DC, 2008b, von Stamm, 2008, Livesey and Moultrie, 2009, Verganti, 2009, Boothroyd et al., 2011, DC, 2012a)
Designing (Process and image)	(Dumas and Whitfield, 1989, Rassam, 1995, Trueman and Jobber, 1998, Mozota, 2003, Press and Cooper, 2003, DTI, 2005, Tether, 2005, Best, 2006, Mozota, 2006, BSI, 2008, DC, 2008a, DC, 2008b, von Stamm, 2008, Livesey and Moultrie, 2009, Verganti, 2009, DC, 2012a)
Design Strategy (Managing Design actions)	(Gorb, 1986, Gorb and Dumas, 1987, Trueman and Jobber, 1998, Dumas and Whitfield, 1989, Jerrard et al., 2002, Bertola and Teixeira, 2003, Mozota, 2003, Press and Cooper, 2003, DTI, 2005, Hertenstein et al., 2005, Tether, 2005, Best, 2006, McCullagh, 2006, Mozota, 2006, BSI, 2008, DC, 2008a, DC, 2008b, Keinonen, 2008, von Stamm, 2008, Esslinger, 2009, Heskett, 2009, Livesey and Moultrie, 2009, Verganti, 2009, DC, 2012a, Fernández-Mesa et al., 2013)
Design Thinking (Managing company)	(Gorb, 1986, Gorb and Dumas, 1987, Bruce and Bessant, 2002b, Bertola and Teixeira, 2003, Mozota, 2003, Press and Cooper, 2003, Mozota, 2006, Conley, 2007, Brown, 2008, Clark and Smith, 2008, Keinonen, 2008, Neumeier, 2008, von Stamm, 2008, Esslinger, 2009, Heskett, 2009, Livesey and Moultrie, 2009, Martin, 2009, Verganti, 2009, Carr et al., 2010, Liedtka and Ogilvie, 2011, DC, 2012a)

The literatures indicates that the three key areas of design are heavily interlinked, influencing each other to provide creative product/service, system/process and organisation culture. However, deconstructing design into three areas clarifies the benefits and requirements of each area to aid better use of design in business. Details of each area will be discussed in the following sections, but in order to identify the relationship of design areas in the business context, the generic management roles of a company's internal stakeholders were first identified. The structure of business differs depending on the company's tradition (including the ownership structure) or the top-level managers' decisions about how to best manage the business, whether top-down or a flat structure (Peter, 1993, Brandt, 2004, Ortega-Argilés et al., 2005, Ghemawat, 2010). This determines the management decision-making hierarchy, but the role of each level of managers can be divided into senior managers, managers, and supervisors and operators (Witcher and Chau, 2014); in this classification, top-level managers and senior managers are classed together. Their time is spent principally on managing the business as illustrated in Figure 2.7, which shows that senior managers tend to concentrate on holistic overall strategic management of a business, whereas supervisors and operators are primarily engaged in managing day-to-day activities.

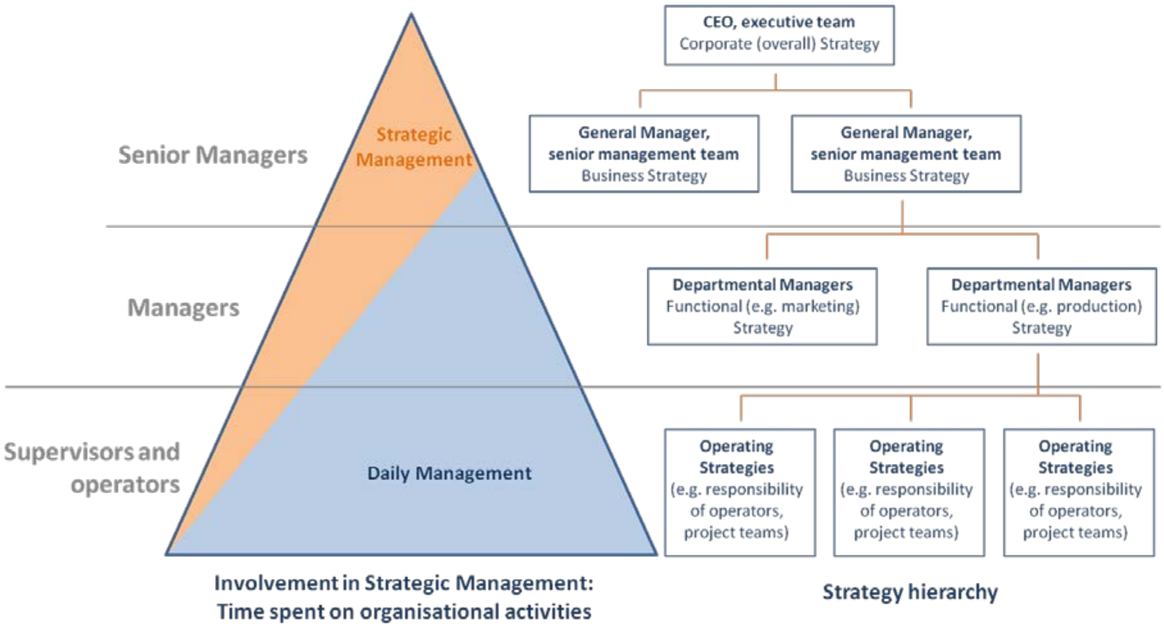


Figure 2.7: Principal management activities of various company stakeholders. Adapted from (Witcher and Chau, 2014)

The areas of design and the business context discussed in this section provide an overview of where design values apply in businesses (Figure 2.8). The placement of each area of designing, design strategy and corporate-level design thinking in Needle's (2010) business context model provides a stable foundation for developing a theory, and reduces the 'fuzziness' of the meaning of design. The business context model is chosen because it provides a comprehensive overview of different business elements, allowing the placement of the various areas of design identified in this section. The business context model emphasises the interlinking relationships between each level, which is similar with close relationship between identified design areas. As already mentioned, the design areas and their relationship with the business context model will be discussed in greater detail in the following sections.

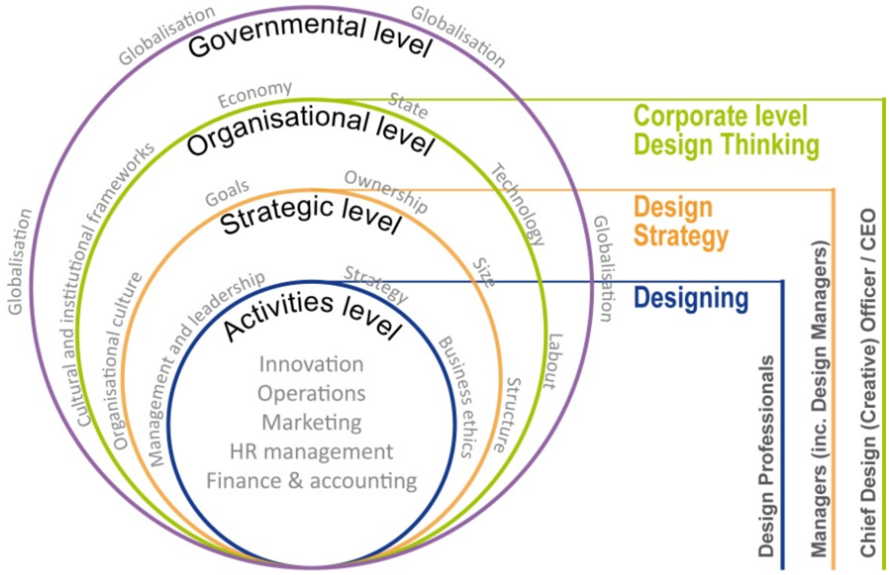


Figure 2.8: Design in the Business context model. Adapted from (Needle, 2010)

2.2.2.1 Designing

Designing (production) is defined as a company's activity to create an artefact, including design for manufacture and engineering design (Lindbeck, 1995, Poli, 2001, Boothroyd et al., 2002). This is traditionally the most familiar area for UK businesses (Tether, 2005) and manufacturing companies (Livesey and Moultrie, 2009, Na and Choi, 2012). Thus it is the only area regarded as 'design' by companies which lack a holistic view of the wider design spectrum. 'Designing' is normally led by professional designers and design engineers, who take into consideration function, aesthetics, ease of manufacture etc., which involve the technical ability to manipulate ideas with appropriate materials, colours, textures, shapes etc., (Tether, 2005, Best, 2006, Livesey and Moultrie, 2009). Designing (for process/image) is an activity which creates mainly intangible outcomes including services, brands, and customer experiences. This part of design activity remains under the umbrella of the conventional 'design process', which involves the design department, often in conjunction with the marketing department, and is therefore regarded as part of "designing" things (Dumas and Whitfield, 1989, DC, 2008b).

The two parts of designing (for production, and process/image) rely heavily on the design professional's discipline-based skill-set. It is also where the immediate effect of design can be observed in a product life-cycle where it provides the means for: (i) product 'development' and market 'introduction,' (ii) helping to maintain in the 'growth' stage by reducing manufacturing costs, and fix unforeseen problems before the 'maturing' stage with the emphasis on distinguishing the product among possible competitors, (iii) creating customisation and adding functionalities to maintain the product's life at the 'maturing' stage, and (iv) making minor refinements to aesthetics or sensory appeal to prolong in the 'decline' stage before discontinuation of the product or radical changes for the product to start another life-cycle (Berkowitz, 1987). The stages are shown in Figure 2.9 which demonstrates the emphasis of design during the product's life-cycle.

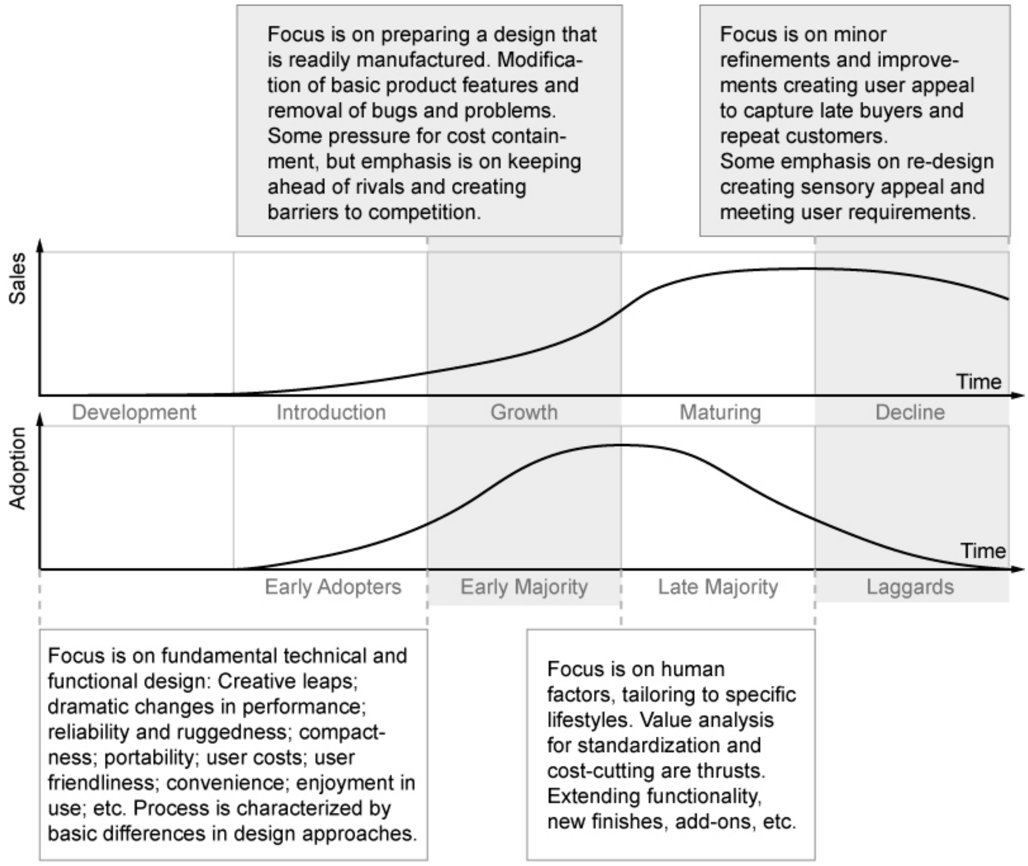


Figure 2.9: Emphasis of design during product life-cycle. Adapted from (Ryan and Gross, 1943, Berkowitz, 1987, Canada et al., 2008)

As with all design areas, the ‘designing’ area is inherently user-focused which provides outcome (in product or service) for the consumers’ benefit, so the success of design in this area is directly related to product sales, profit margins, and customer satisfaction (Cooper and Press, 1995, Rassam, 1995) with which companies can increase their competitiveness and prolong growth (Mozota, 2002, DC, 2008b, von Stamm, 2008). The nature of the work involved means ‘designing’ can be placed in the ‘activity level’ of a company, in Needle’s model of business in context (2010). This level of an organisation includes functional groups for innovation, operation, marketing, human resource management, and finance and accounting, all interlinked and influenced by each other, and influencing the overall business context. Design works as a part of a system in NPD at this level, where it provides creativity and technical design skills to ensure product success in the market (Hertenstein et al., 2005).

2.2.2.2 Design strategy

Needle states that the business context includes the “strategic level” of a company: management decisions which determine business activities, including the range of products and services, marketing budgets, resource management and employees. Design strategy operates at the strategic level, dealing with the management of design in a firm, usually conducted by design managers and/or senior managers. Needle’s definition of strategy reflects many literatures which describe design strategy as a set of objectives and the methods required to achieve these objectives. Many literatures emphasise the importance of design strategy in manufacturing (Dumas and Whitfield, 1989, Cox, 2005, Best, 2006, DC, 2008b, Tether, 2009, DC, 2010, Fernández-Mesa et al., 2013), where the main function of design strategy is to manage design in an organisation which ensures that ‘designing’ can be used as a strategic business tool. It is “commonly used to mean a long-term plan for implementing design, particularly at a product... practised by skilled experienced designers and design managers” (Stevens and Moultrie, 2011:476). It is therefore vital for consumer adoption in the product life cycle (Figure 2.9), with emphasis on: (i) endorsing, (ii) curating, (iii) integration, (iv) economising, (v) play, and (vi) refreshing to enable success in the market (Canada et al., 2008), (see Table 2.6), to provide the essential connection between the consumer and the business strategy (McCullagh, 2006).

Table 2.6: Design strategy emphasis for different adopters in the product lifecycle

Adopters (consumers)	Strategic Emphasis	Description
Innovators	Endorse	Explain the benefits and function of a nascent technology to the world
Early adopters	Curate	Create icons which are selective in their functionality
Early majority	Integrate	Provide solutions which fit into people's lives
Late majority	Economise	Drastically cut production costs of already successful technologies
Laggards	Play	Find new ways to add value which do not depend on technical differentiation
New market	Refresh	Reinvent existing offerings and renew technical differentiation to reach new markets

Source: Adapted from (Canada et al., 2008)

The influence of design strategy is not only limited to 'designing' activities where it also has an important role in the company's innovation process and other processes, including the production process, using design's creativity, empathy and holistic/systematic thinking-skills in order to increase efficiency, feasibility and collaboration (Topalian, 2013). It is distinguished from the 'designing' area of design because of the "deep understanding of values, attitudes, and behaviour of the target consumer; the nature of the company's value, essence, and character; and the time-based trends that serve as the backdrop to the product or service experience" (Vossoughi, 2007:74). Design strategy therefore provides a company with both a design-centric process management and business strategic influences. Design managers both internal or external to a company take on the role of mediator between these two areas (Dumas and Whitfield, 1989, Weiss, 2002, Joziasse, 2010), working as a catalyst to ensure the company's strategy is influenced by design professionals' creativity (creating business strategy) or the company's designing activities are directed towards achieving the company strategy (following the business strategy), creating appropriate processes to enable a seamless integration of creative and logical thinking.

2.2.2.3 Corporate-level design thinking

Further to the development of a design strategy, the capability of design in the wider context of a company is also considered. Recently described as 'design thinking', it is concerned with how the design principle can be used to enable a business to deal with the rapid complex changes which organisations face in the modern market (Brown, 2009, Martin, 2009, Liedtka and Ogilvie, 2011, Mootee, 2013). Diffusion of design in business is not new: Gorb and Dumas (1987) and Blaich (1988) described the convergence of design in business management. Similarly, in a speech at Innovation Night at The Royal College of Art, London, Nussbaum (2007) argued that the CEO must be “designers”, referring to design thinking as a management principle. Further to this argument, The Design Council and a Warwick University study (DC, 2014) show the importance of the business leader’s appreciation of design to ensure a firm’s success, while Turner (2000) argues that design must be embedded in a company’s “DNA”, led by the executive leadership with all employees as design champions. Topalian (Topalian, 2012, Topalian, 2013) also emphasises the importance of design at the top level by stating that it is the responsibility of business executives to ensure that the wider design spectrum is integrated in the business in order to avoid sabotaging the company.

Design thinking as a principle of thinking to become more creative, and as a tool which can be applied during the decision-making process, has a distinct advantage over a conventional management system (Walker, 1990, Liedtka, 2010). As creativity is one of the most sought after qualities in a leader chosen by the CEO (Businessweek, 2010), design thinking has become an important agenda for top-level managers. Liedtka and Ogilvie (2011:12-17) emphasise how business can learn from the elements of design:

- *First, design is all about action, and business too often gets stuck at the talking stage.*
- *Second, design teaches us how to make things feel real, and most business rhetoric today remains largely irrelevant to the people who are supposed to make things happen.*
- *Third, design is tailored to dealing with uncertainty, and business’s obsession with analysis is best suited for a stable and predictable world.*
- *Fourth, design understands that products and services are bought by human beings, not target markets segmented into demographic categories.*

According to Martin (2009) and Mootee (2013) design thinking is about balancing analytical thinking and intuitive thinking (see Table 2.2 for the differences between business- and design-led logics) which should be demonstrated by business leaders (top-level managers) to enable sustainable advantage over the competitions derived from considering desirability, viability and feasibility in their decision-making (Brown, 2009), as shown in Figure 2.10.

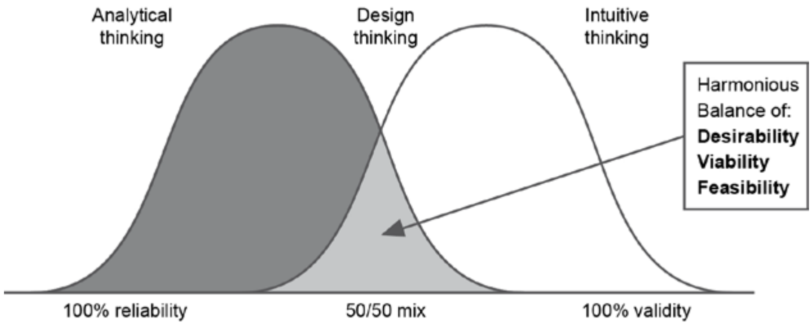


Figure 2.10: The predilection gap for design thinking and its key considerations. Adopted from (Brown, 2009, Martin, 2009)

In this research, the term ‘corporate-level design thinking’ is used to distinguish the use of design thinking by senior and top-level managers and design practitioners. This is to distinguish between design practitioners’ use of design thinking to develop products/services and the application of design thinking to manage the whole company. Therefore, referring to Needle’s business in context model (Figure 2.8), corporate-level design thinking is placed at the organisational level because it is concerned with goals, structure, ownership, and organisational or corporate culture.

2.3 Innovation

Innovation is important in almost all socio-economic areas. Baregheh et al. (2009) provide a theoretical study of the definition of innovation from various disciplines, ranging from business and management, economics, organisation studies, innovation and entrepreneurship, technology, science and engineering, knowledge management, and marketing. They describe innovation as a multi-stage organisational process which transforms ideas into new/improved products, services or processes to advance, compete, and differentiate in an appropriate market. Innovation, like design, has several areas of emphasis depending on where the most important “change” for a company lies, which will be discussed further detail in this section. One of the simpler principles of innovation is described by the Department of Trade and Industry (DTI) (now part of the Department of Business, Innovation & Skills) as “the successful exploitation of new ideas” (DTI, 2003:8). This brief but powerful description, still widely used by the UK government, is seen in the manufacturing sector as a way to compete in the globalised market with challenges from developing countries, including China and India (BIS, 2010c, BIS, 2011a).

2.3.1 Fundamentals of innovation

Tidd et al. suggest that innovative firms are twice as profitable as other companies, where innovative companies are defined as those using innovation to differentiate their products/services from competitors’ (Tidd et al., 2005). The Boston Consulting Group’s (BCG) 2014 survey of senior executives - in which approximately seventy-five per cent of 1,500 business leaders regarded innovation as important for their companies (BCG, 2014) – indicated that it must be an important priority for top-level managers, if a company is to make the most of the potential benefits of innovation. However, the survey also showed that executives were less confident of their company’s innovation capabilities, because they were concerned whether their company was prepared to break through the barrier of radical changes required to harness innovation. Innovation inevitably involves change, uncertainty and risk for the company, which requires a willingness to embrace failures which may affect the very core of a company (Christensen, 1997, Le Masson et al., 2010, Fisher, 2014). However, despite the risk of failure, it is imperative for companies to secure competitiveness to survive in a turbulent rapidly-changing market (Peters, 1997, Storey, 2000, Tucker, 2001, Tidd et al., 2005, Jolly, 2010, PWC, 2013b).

The degree of novelty is often used to distinguish between innovation which represents minor and incremental changes (incremental innovation), and complete and radical changes (radical innovation). Incremental and radical innovation relate to a range of changes from component changes to system change (see Figure 2.11); incremental change consists of localised changes, whereas radical change makes systematic changes for a company or even the sector, industry or society (Bessant and Tidd, 2007).

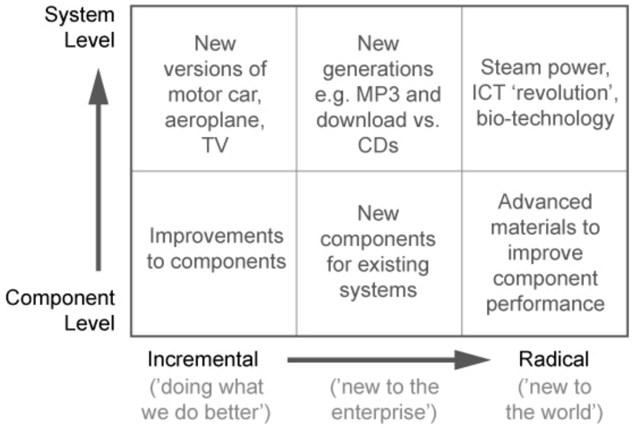


Figure 2.11: Dimensions of innovation. Adapted from (Bessant and Tidd, 2007)

Radical innovation can achieve great impact by increasing company competitiveness and even change the nature of competition in favour of the innovator, so the term is synonymous with breakthrough and discontinuous innovation (HBE, 2003). Many companies aspire to this, when considering the importance of innovation (PWC, 2013a, BCG, 2014). However, most innovation happens incrementally (Ettlie, 2006), particularly in British manufacturing SMEs (Mosey et al., 2002) and in global manufacturing companies (PWC, 2013c), supported by 'lean' manufacturing which offers continuous improvement to enable sustained growth for a business (Tidd et al., 2005). Radical and incremental innovation are not mutually exclusive and can coexist within a company, depending on the firm, sector and industry (OECD, 2005, Malerba, 2005).

Radical and/or incremental innovation are achieved through a systematic process which usually includes: (i) identify the opportunity, (ii) assess the needs, (iii) generate or acquire new ideas, (iv) design the product, (v) evaluate and select the most appropriate ideas, (vi) manufacturing (production), (vii) introduce to the market and conduct sales activities (Tuominen et al., 1999). The process, which has developed over many years, is described by Rothwell (1994) as four generations of innovation models, particularly for manufacturing companies, starting with the linear processes of technology push or market pull, which then evolves into a more flexible integrated process. The first generation innovation process (technology push) depends predominantly on developing a basic science which is translated into new technology and then realised in a product. The second generation process (market pull) is also a linear process which identifies the need for a market and develops products to satisfy the market's needs. The third generation model, also called the 'Coupling' model, is the interlay of new technology and needs to generate ideas appropriate to the marketplace. Finally, the fourth generation - which includes 'integration' and a 'parallel' development innovation process - integrates internal functions in parallel to develop a new product which is integrated with external factors, as shown in the third generation innovation process (Figure 2.12).

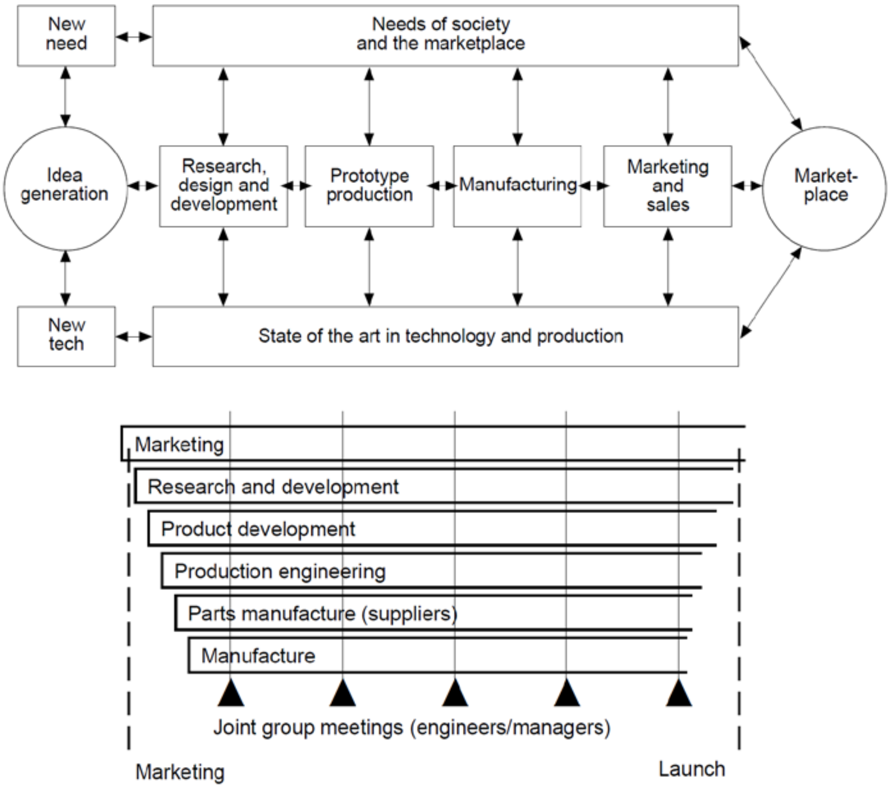


Figure 2.12: Third generation innovation process model - The 'Coupling' model (top), and the fourth generation 'integrated' innovation process (bottom) (Rothwell, 1994:10-12)

The development of the innovation process shows the increased complexity of innovation of both internal and external factors, indicating that it must be managed with strategic intent in order to be successfully implemented. In this respect, Hansen and Birkinshaw (2007) created an innovation value chain which provides a holistic view of the innovation process, in order to easily identify the elements of innovation in a company (see Figure 2.13). In this value chain, the key question and performance indicators are identified for each step including: (i) idea generation – in-house cross-pollination (across departments), (ii) external conversion – selection and development, and (iii) diffusion – dissemination across the organisation. The inclusion of “diffusion” to share ideas across the company is particularly interesting because it provides a platform on which an organisation can develop its knowledge base and, if managed effectively, knowledge management (KM) can also be used to create new ideas, making the value chain a virtuous cycle.

	IDEA GENERATION			CONVERSION		DIFFUSION
	IN-HOUSE Creation within a unit	CROSS-POLLINATION Collaboration across units	EXTERNAL Collaboration with parties outside the firm	SELECTION Screening and initial funding	DEVELOPMENT Movement from idea to first result	SPREAD Dissemination across the organization
KEY QUESTIONS	Do people in our unit create good ideas on their own?	Do we create good ideas by working across the company?	Do we source enough good ideas from outside the firm?	Are we good at screening and funding new ideas?	Are we good at turning ideas into viable products, businesses, and best practices?	Are we good at diffusing developed ideas across the company?
KEY PERFORMANCE INDICATORS	Number of high-quality ideas generated within a unit.	Number of high-quality ideas generated across units.	Number of high-quality ideas generated from outside the firm.	Percentage of all ideas generated that end up being selected and funded.	Percentage of funded ideas that lead to revenues; number of months to first sale.	Percentage of penetration in desired markets, channels, customer groups; number of months to full diffusion.

Figure 2.13: The innovation value chain (Hansen and Birkinshaw, 2007:124)

2.3.2 Expanding parameters of innovation

The parameters of innovation have widened in a way similar to those of design. Innovation was often seen as product or service breakthroughs, whether radical or incremental changes, especially in the UK manufacturing sector. However, NESTA emphasises the importance of “hidden innovation” in order to compete globally and not remain “locked-in” to existing technologies and business models (NESTA, 2008b). NESTA calls this Total Innovation, which includes new organisational structures and business models using existing technologies and beyond. Although some authors separate the business model and innovation (Teece, 2010), this research regards the business model as part of innovation. Tidd et al. (2005) separate the types of innovation into product, process, position and paradigm innovations, with which the OECD (2005) concurs, describing the innovation types as product, process, marketing and organisation. Boer and During (2000) describe a manufacturing perspective of innovation where the separation lies in organisational innovation, where it concentrates much more on a firm's Total Quality Management (TQM). Keeley et al. (2013) divided this further into ten types of innovation (Table 2.7): profit model, network, structure, process, product performance, product system, service, channel, brand and customer engagement - covering the many aspects of innovation identified in an organisation by the Deloitte international innovation consultancy perspective.

Table 2.7: Descriptions of types of innovation

Types of Innovation	Descriptions	Cases
Product Performance	New or improved product in a market - simplification, sustainability, customisation etc.,	Dyson: successful introduction of dual cyclone technology
Product System	Product ecosystem including extension to existing products, product service combinations etc.,	Microsoft: MS Office as a bundle of productivity software
Service	Enhancement of utilisation, performance, and value of offerings including warranty and customer service	Hyundai: 'Assurance' of being able to end the contract if they lose the job within a year
Channel	Connection between product/service to the users, including physical stores to e-commerce	Nespresso: providing various means to purchase coffee capsules
Customer Engagement	Developing a meaningful connection with the customer/user including appropriate communications with them	Apple: Apple stores and World Wide Developers Conference (WWDC)
Brand	Ensuring the users recognise, remember, and prefer the product/service. For B2B, this can include the final users to build preferences and bargaining power	Virgin: successfully increasing the brand portfolio
Process	Improvement of activities and operations in production including lean production	Toyota: lean production system
Network	Collaborating to gain the advantages of other companies' resources, including sharing risk of new offerings and open innovation	GSK: co-innovation platform development
Structure	Organisation of company assets - hard, human, or intangible - to create value	Whole Foods Market: decentralisation of management
Profit Model	Converting firm's offerings and other sources of value into cash including pricing, pay-per-use, subscription, etc.,	Gillette: business model driven innovation

Source: Adapted from (Keeley et al., 2013)

The research shows that product and process innovations are relatively common in categorising innovation. The discrepancy lies in innovation which involves business strategy and organisational management. In this research, the principles of organisational innovation described by Boer and During (2000) are used in conjunction with the business model and market innovation, providing an overview of the organisational innovation. However, acknowledgement of broader innovation parameters has been slow to filter through to UK manufacturing firms where technological and product innovations are still the predominant interpretation of innovation (NESTA, 2009, Na and Choi, 2012). This is predictable, especially in high-value manufacturing where technology push is an important competitive advantage for competing in the global market (PWC, 2009, TSB, 2012c). The PWC global innovation survey of 1,757 executives (top-level managers) supports this argument. Figure 2.14 shows the global trend of businesses prioritising product, technology and service innovations over process, and business model innovations.

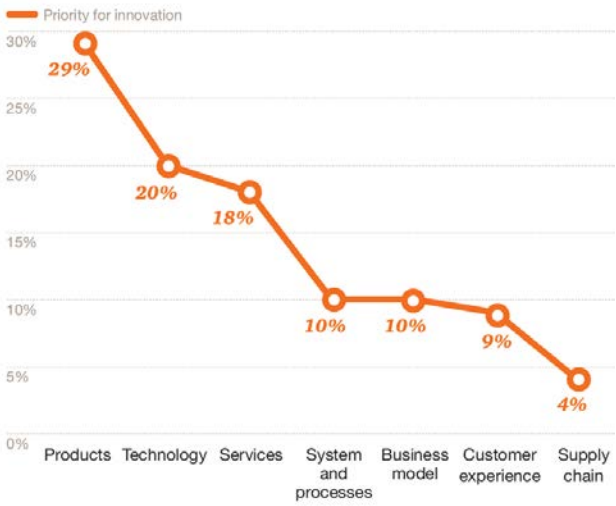


Figure 2.14: Priority of innovation for the next 12 months (PWC, 2013a:32)

The survey report, however, also argues that there is a noticeable trend from businesses which show a significant increase of focus in developing business model innovation. As NESTA suggests, embracing other areas of innovation is an increasingly important agenda as technological innovation is now sought by emerging economies including China and India (NESTA, 2008b). Tucker (2001) suggests four principles to consider innovation as a company's core competencies, where it must be i) comprehensive, ii) include an organised, systematic, and continual search for new opportunities, iii) involve everyone in the organisation, and iv) constantly improve the company climate, indicating why comprehensive development of different areas of innovation (i.e. 'Total innovation') must be practised in order to be competent in innovation, which will lead to increased competitiveness and sustained growth.

Further understanding of the different areas of innovation requires a unified definition. This research identified the innovation areas from the literature review, including: (i) technological innovation, which focuses on the development of new or improved technologies, (ii) product/service innovation, which develops and produces products/services for the market, (iii) process innovation, which aims to improve the product/service development processes e.g. NPD and production processes and product delivery processes e.g. logistics and sales processes, and (iv) organisational innovation, which improves organisational-level management creating company vision and values, strategies and business models to enable a company to embrace innovation culture and succeed in the market. These areas are closely linked, one area often requiring another area to practise innovation effectively (Bessant and Tidd, 2007) e.g. for successful development and delivery of a product (product innovation), appropriate technology needs to be available (technology innovation) with processes which encourage creativity and maximise efficiency (process innovation) and the sales channels which initiate and maintain sales (organisational innovation). Each area of innovation will be discussed further in later sections.

2.3.2.1 Technological innovation

Technological innovation is sometimes regarded as part of product innovation as it provides technical advancements which are included in the product itself. However, this is discussed separately in this section because it is an important key to manufacturing companies' long-term competitiveness (Freeman, 1994, Sen and Egelhoff, 2000, Guan et al., 2006). It is traditionally driven by public research which initiated breakthrough innovations such as "the internet, GPS, and the MRI scanner" (Miles et al., 2009:15). However, company-driven R&D also delivers technological innovation which leads to the improvement of: (i) efficiency, which considers R&D/technology productivity and acquisition in relation to product performance, and (ii) effectiveness through successful implementation of R&D/technology in creating new products, licences of parents and thus increases company profits (Chiesa et al., 1996). Technological innovation is the focus of innovative manufacturing by the Engineering and Physical Science Research Council (EPSRC), which created Innovative Manufacturing Research Centres (IMRC, latterly known as Centres for Innovative Manufacturing-CIM) to provide a collaborative environment for UK universities and manufacturing companies to develop world-class knowledge and support up to Technology Readiness Level (TRL) 3 (TSB, 2008, EPSRC, 2010).

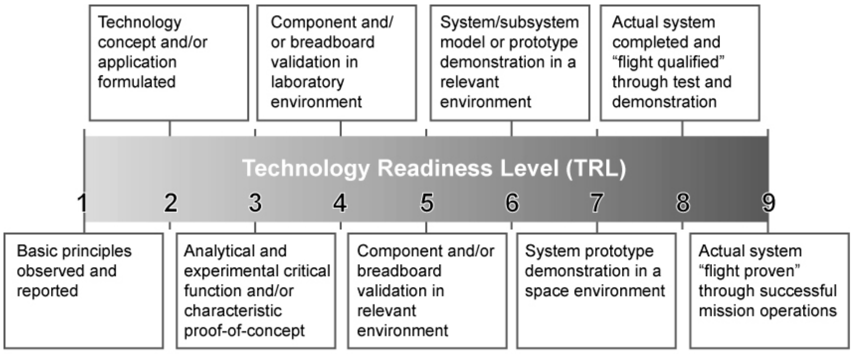


Figure 2.15: Technology Readiness Level (TRL). Adapted from (NASA, 1995)

TRL (NASA, 1995), originally developed by the National Aeronautics and Space Administration (NASA), is readily used as an indicator of the nine levels of technology development and implementation: (i) scientific principle discovery, (ii) technology concept rationale justification, relative to the appropriate application environment, (iii) analytical and experimental proof-of-concept, (iv) laboratory-based validation as a component - initial prototyping, (v) relevant environment validation as a component, (vi) demonstration in the relevant environment as a subsystem, (vii) system prototype demonstration in a real-life environment, (viii) application (production) of the system, including the developed technology, and (ix) proven technology through successful launch of the system (Figure 2.15). Commercially, the system can be regarded as a product which includes technological components developed by R&D through scientific discoveries (TSB, 2012b). This clarifies technological innovation within the holistic process of innovation systems because of its focus on technology development. This research identifies technological innovation as being between TRL 1 and 3 where the discovery of relevant technology is developed, which leads to innovation either exclusively in first generation innovation (technology push) or as a part of a system in the third and fourth generation (integrated process) of innovation (Rothwell, 1994), as explained in Section 2.3.1.

The relative importance of technology in the market in relation to the contextual variables is identified by Balachandra and Friar (1997) (see Table 2.8). They argue that technology factors are very important - compared to market and organisational factors - for creating high technology where it involves rapid development of technology which can provide early market entrance compared to low technology (Balachandra and Friar, 1997). This can be an important option for manufacturing companies to gain competitive advantage, as technology development is regarded as a key supporting activity to create value for companies (Porter, 1985).

Table 2.8: Scheme of relative importance for combinations of contextual variables

Contextual Variable			Market Factors	Technology Factors	Organisation Factors
Innovation	Technology	Market			
Incremental	Low	Existing	Very Important	Less Important	Very Important
Incremental	Low	New	Very Important	Less Important	Very Important
Incremental	High	Existing	Very Important	Very Important	Important
Incremental	High	New	Important	Very Important	Important
Radical	Low	Existing	Important	Important	Important
Radical	Low	New	Less Important	Important	Important
Radical	High	Existing	Important	Very Important	Important
Radical	High	New	Less Important	Very Important	Very Important

Source: (Balachandra and Friar, 1997:284)

2.3.2.2 Product/service innovation

This research considers product/service as an outcome of the innovation processes conducted by an organisation. The aim of product/service innovation is therefore to deliver changes in products/services to the appropriate market and users, to generate profit by enabling growth through increasing competitiveness (Balachandra and Friar, 1997, Tucker, 2001, OECD, 2005, Trott, 2005, Ettlie, 2006, Bessant and Tidd, 2007, Salunke et al., 2011, Goodridge et al., 2012, Keeley et al., 2013, Coad et al., 2014). As the outcome of product/service, innovation can be explicit, particularly for manufacturing companies (products), resulting in financial achievements through increased sales (turnover) and profit margins by the introduced product/service. It is therefore an important area for measuring a company's innovation capabilities (Coad et al., 2014). In order to achieve these benefits, product/service innovation provides differentiation (Bessant and Tidd, 2007) among the competitors, which is also driven by: (i) intense international competition i.e. through globalisation, (ii) fragmented, demanding markets - increasingly sophisticated and demanding customer expectation, and (iii) diverse and rapidly changing technologies - rapid growth of the breadth and depth of technological and scientific knowledge (Wheelwright and Clark, 1992). Different product development programmes can lead to product innovation, with different advantages for companies. These types of development include: (i) new to the world – creating a new market, (ii) new product line – new entry to an existing market, (iii) add to existing products – expanding the product line (range), (iv) improve or revise – improving the current product line, (v) repositioning – changing consumer perception of the products, and (vi) cost reduction – increasing unit volume or staying price competitive (Annacchino, 2006). The contribution of the types of product development in the economy and company are shown in Table 2.9, which is categorised into radical and implementation product innovations to illustrate their impact on business performance.

Table 2.9: Product innovation dimensions and types of product developments

Innovation dimension	Type of development	Time to market	Revenue contribution to economy	Revenue contribution to company	Company positioning strategy	Potential margin impact
Radical	New to the world	Longest	Highest potential	Highest potential	Market development	Highest
	New product line	Long	High potential	High potential	Market development	High
Incremental	Add to existing	Medium	Medium potential	Medium potential	Line complete	Medium
	Improve or revise	Short	Little potential	Medium potential	Market share	Medium
Radical / incremental	Repositioning	Shortest	Little potential	Medium potential	Market share	Medium
	Cost reduction	Shorter	Little potential	Medium potential	Raise margin	Medium

Source: Adapted from (Annacchino, 2006)

Product and service innovation are considered together in this research as they share similarities as the outcome or offerings in a market for customers and users (Tidd et al., 2005). UK manufacturing companies' product innovation is still focused without any in-depth mention of service innovation or sometimes of integrated services as part of product innovation (Boer and During, 2000, OECD, 2005, BIS, 2010c). However, the importance of service innovation as discussed by Neely (2007) as a key to compete with emerging countries and against cost competitiveness, is recognised by leading manufacturing companies (BIS, 2010c, PWC, 2013a). It is also recognised as having consistently high performance over time for product-centric manufacturing companies which are considering service innovation (Gallouj and Weinstein, 1997). Service innovation follows the generic innovation process (see Section 2.3.1) (Rothwell, 1994), but the capability of service innovation differs slightly as mentioned by Kindström et al, (2013). They describe the dynamic capabilities, including areas of process and organisational innovations which are directly involved to increase a company's service innovation capabilities: (i) sensing – understanding the internal and external components of customer-related service, (ii) seizing the opportunities identified by managing the development and delivery process, and (iii) reconfiguring service systems internally and externally to balance product and service innovations (Table 2.10).

Table 2.10: Service innovation capabilities

Dynamic capabilities	New service innovation	Description
Sensing	Customer-linked service sensing	Building up deep customer knowledge, including institutionalising feedback loops and creating organisational roles, systems, and processes which continuously capture and relay customer demands.
	Service system sensing	Building up an understanding of the entire service system, including links to partners and suppliers, and creating network skills.
	Internal service sensing	Building up internal sensing: e.g. opportunities related to the integration of products and services and the detection of decentralized initiatives. Having a structured service development process to address this factor.
	Technology exploration	Scanning and exploring sources outside the service system, primarily related to more radical technological changes.
Seizing	Service interaction	Interacting and co-developing with customers and partners to understand, visualise, and deliver value propositions. Involves processes, roles, and skills to interact and change together with customers.
	Managing service delivery process	Having the ability to restructure internal and external resources swiftly, for the delivery of new or improved services, including roles dedicated to services at both operational and strategic levels.
	Structuring the service development process	Structuring a service development process and being flexible as the process develops.
	Adopting new revenue mechanisms	Rolling out new revenue mechanisms based on service value, such as availability and customer productivity. The ability to visualise the value of new, often intangible services and solutions for a wide array of actors in the service-delivery system.
Reconfiguring	Orchestrating the service system	Managing and transforming the service system, especially managing external actors central to the performance of the service. An ability to extend the resource base into new markets and services, and to incorporate complementary resources and co-specialisation. Reconfiguring roles, resources, locus of control, and power in the service system.
	Balancing product and service innovation related assets	Maintaining a balanced relationship between the service organisation and the product organisation, necessitating the creation of roles designed for service on all levels of the organisational structure.
	Creating a service-oriented mental model	Often referred to as a service logic; implies a learning dimension.

Source: Adapted from (Kindström et al., 2013)

The research considers the product and service innovation together as one area of innovation. This is because the research identified the importance of product and service innovation to increase manufacturing companies' competitiveness and how they should be closely linked, to maximise the company's innovation capabilities.

2.3.2.3 Process innovation

Process innovation is the incremental or radical improvements to creating and delivering products/services for organisations (Trott, 2005, Bessant and Tidd, 2007) which: (i) improve quality to fulfil customer expectations, (ii) reduce the lead time of product development, production and delivery to a market, and (iii) reduce manufacturing costs, to increase profit, which is fundamental to business success (Cumming, 1998). Some researches take a narrower view of process innovation, where only changes in new or significantly improved (radical) process are considered (OECD, 2005, Coad et al., 2014). However, as discussed earlier, this research takes on the broader perspective of innovation which includes both incremental and radical innovation. Product innovation is followed by process innovation (Utterback, 1986) so they are closely linked, enabling optimised innovation execution in a company. The three critical parameters of business, as described earlier, potentially work against each other (see Figure 2.16) where by improving quality, both the lead time and cost are likely to be increased. Similarly, by reducing the lead time, quality may decrease with increased costs (Cumming, 1998).

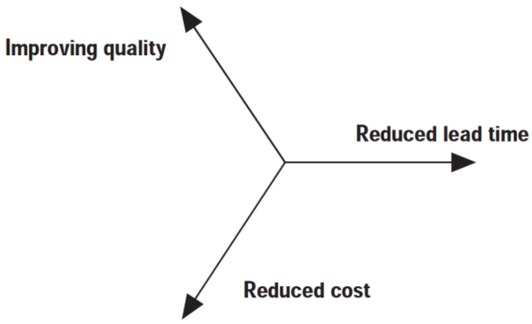


Figure 2.16: Three critical parameters of business (Cumming, 1998:27).

Process innovation's role is to achieve parameter(s) with minimum sacrifice of other competing parameter(s) to meet a manufacturing company's strategic priorities e.g. a new product development (NPD) process can include computer aided design (CAD) and computer aided manufacture (CAM) to reduce time and cost, effective prototyping to increase quality and reduce development costs, and information management (also referred to as knowledge management) to enable fast sharing of past experiences to reduce time and increase quality (Cumming, 1998). Furthermore, manufacturing companies can use flexible manufacturing systems (FMS) to increase quality and reduce costs while also reducing the lead time to deliver products to the customers (Boer and During, 2000). It is closely linked with the lean (agile) manufacturing process which involves minimising waste in defects, inventory, processing (resources in space, energy and people for production), waiting (idle time in production), motion (reduction of unnecessary movement in production), transportation and over-production, to optimise the manufacturing process (Katayama and Bennett, 1999, Shah and Ward, 2003, Wilson, 2010). The open innovation principle, which is closely linked with collaboration (through strategic alliances and integration of consumers in product development), is also part of process innovation in this research because it enables companies to develop new innovation processes (Enkel et al., 2011). Process innovation thus requires a strategic balance between business goals and process improvements in production, product developments, and the innovation process itself.

2.3.2.4 Organisational innovation

The research identified some discrepancies in the area of organisational innovation (Section 2.3.2). However, this research takes a broader view of organisational innovation including the paradigm (Tidd et al., 2005) and the business model (Chesbrough, 2007, Teece, 2010). Some elements of market innovations which involve strategic changes e.g. product placement (sales channel) and pricing strategy (OECD, 2005) are also included in organisational innovation, because the principle of these different types of innovations involves improvement at an organisational level where decisions are normally made by top-level managers which change strategic directions, and often change the organisation’s innovation culture (Utterback, 1986, Storey, 2000, OECD, 2005, Tidd et al., 2005, Teece, 2010). Organisational innovation therefore involves incremental and/or radical changes of management principles, processes and practices which organise, lead, co-ordinate or motivate the organisation in order to “create long-lasting advantage and produce dynamic shifts in competitive position” (Hamel, 2006:72). As with other areas of innovation discussed in this section, organisational innovation is closely linked with other areas of innovation within the innovation system, which has the overarching responsibility for creating continuous innovation in an organisation by: (i) increasing the organisation's reputation for innovation, (ii) attracting creative people, (iii) organisational encouragement of creativity and innovation, (iv) development of innovative products, (v) accepting new ideas, (vi) motivating employees, (vii) high morale and retention of creative people (Trott, 2005). Figure 2.17 shows this "virtuous circle of innovation" to increase competitive advantage.

Figure 2.17: Virtuous circle of innovation (Trott, 2005:96).

Organisational innovation is also closely linked with Toyota's production system or Total Quality Management (TQM) where the holistic (company-wide) approach of continuous improvement for quality in relation to customers' expectations is vitally important in managing successful innovation (Boer and During, 2000, Needle, 2010). Organisational innovation is thus involved in the management of the external factors of a business, i.e. business model or paradigm innovations which provide the underlying "mental model" which shows the collective value proposition of the business (Teece, 2010, DaSilva and Trkman, 2014). In this respect, the business model is inherently a conceptual array of elements which influence holistic business operations (see Figure 2.18) including the selection of technologies and product/service features appropriate for the changing market and user needs, and developing and delivering products/services which create value for customers, and thus generate profit for the company.

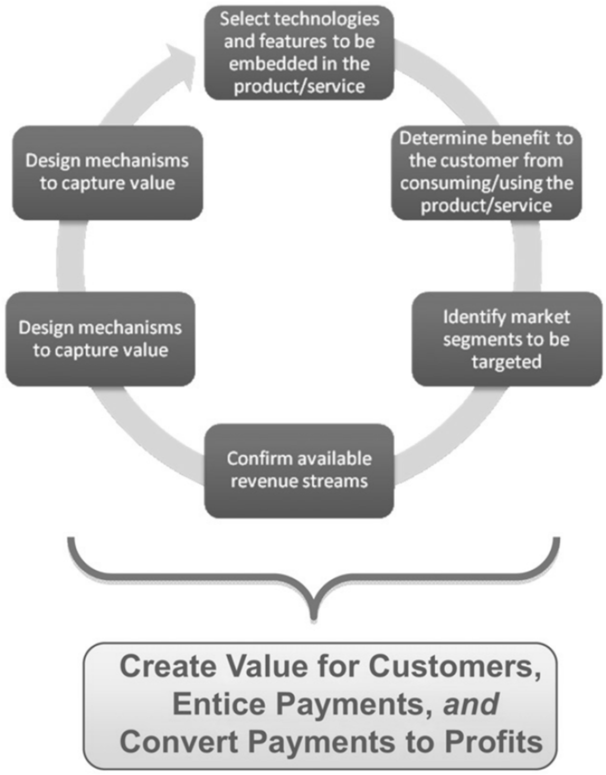


Figure 2.18: Elements of business model design (Teece, 2010:173).

The research identified the close relationship between organisational innovation and strategic management of a business, with top-level managers' decision-making in order to successfully practice organisational innovation to enhance competitiveness.

2.4 Design and innovation

Many studies found that design contributes significantly in almost all aspects of innovation whether it is incremental or radical innovation (Mozota, 2003, Utterback et al., 2006). However, design is not synonymous with innovation (von Stamm, 2008); innovation contributes more broadly in an organisation, requiring inputs from R&D, marketing, strategic management etc., Design, whether as an activity to produce product or as a company philosophy, is a catalyst and enabler for innovation to have more effective outcomes. It 'couples' between technical possibilities and user/market demands and opportunities, and can infuse a company's internal functions with external influences -

trend, new material and technology, consumer behaviour and patterns of demand (Walsh, 1996). The similarities between innovation and design are evident in how they expand their roles in an organisation. As innovation expands, it becomes more complex, with numerous ideas of where in a business it may be implemented. As with design, its contribution is now acknowledged in more areas of businesses because of the blurring of the boundaries of design and how it can be used in a business to harness leaders' and managers' creativity, and influence how a product appears and functions.

2.4.1 The relationship between design and innovation

Designers develop an innovation-conducive mindset through their personal preferences and training (von Stamm, 2008). Mozota (2003) notes that design input is required for every incremental or radical innovation, and Roy (1994) states that innovation capability is interlinked with design input. Design can manipulate and visualise 'creativity' to solve complex or 'wicked' problems at different levels of an organisation, including understanding the complexity of the market and of user needs, creating products/services which bring return of investment and profit margins while considering social responsibility, and organising the business to embrace rapid changes in the business environment through innovation (Neumeier, 2008). This problem-solving ability is an essential part of cultivating innovation (Kelly, 2001, HBE, 2003, Hansen and Birkinshaw, 2007, Jolly, 2010). The DTI described design as a bridge between 'creativity' and 'innovation' where design links scientific knowledge and new technology (DTI, 2005) (see Figure 2.19). In the DTI report, innovation is seen as the successful implementation of new ideas provided by creativity, although design is still seen as discipline-based activities: graphic, interior, fashion, industrial and engineering design within a business.

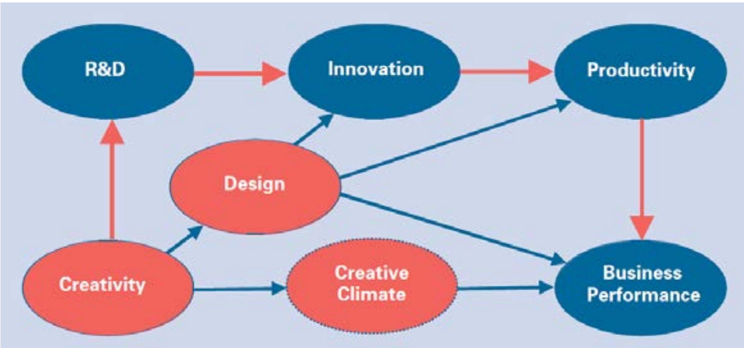


Figure 2.19: The relationship between creativity, design and innovation (DTI, 2005:3)

Key literatures identify the relationship between design and innovation (see Table 2.11), where the areas of design and innovation identified in the research include designing, design strategy and corporate-level design thinking for design, and technological, product/service, process and organisational innovations.

Table 2.11: Key literatures discussing the relationship between design and innovation

Design areas*			Innovation areas**			Reference
D	DS	CLDT	TI	P/S/Pr	OI	
•	•	•	•	•		(Acklin, 2010)
•	•	•	•	•	•	(Battistella et al., 2012)
•	•	•	•	•	•	(Bertola and Teixeira, 2003)
•	•	•	•	•		(Bruce and Bessant, 2002a)
•	•		•	•		(CEC, 2009)
•	•			•		(Chiva and Alegre, 2009)
•	•	•	•	•	•	(DC, 2011)
•	•		•	•		(Dell'Era et al., 2010)
•	•		•	•		(Fernández-Mesa et al., 2013)
•	•			•	•	(Kyffin and Gardien, 2009)
	•	•		•	•	(Mootee, 2013)
•	•	•	•	•	•	(Mozota, 2003)
•	•		•	•		(Nichols, 2013)
•	•		•	•		(Tether, 2009)
•	•	•	•	•		(Verganti, 2009)
•	•	•	•	•	•	(von Stamm, 2008)
•	•		•	•		(Walsh, 1996)

N.B. *In the design area, D=Designing, DS=Design Strategy, CLDT=Corporate-level Design Thinking. ** In the innovation spectrum, TI=Technological Innovation, P/S/Pr=Products/Services/Processes Innovation, OI=Organisational Innovation)

The research identified three key design areas which influence innovation in a company. Firstly, design is used as a visual aid to provide "symbolic representation" to illustrate the innovation vision (Swann and Birke, 2005). This can be expanded to include the ability of design to visually represent creativity through sketches, CAD modelling, cognitive art (diagrams, models), storyboards, the customer journey etc., to envision information and ideas which are easily recognised by innovation stakeholders (Nelson and Stolterman, 2012, Kumar, 2013, Bryden, 2014). It uses design's technical ability to think holistically to build on information to generate schematics of a given system, to align relevant and important aspects of a company's strategic directions with innovation. Design's visualisation ability includes three-dimensional objects (prototype models): in the early stage, prototypes can manifest the form and structure of the product ideas generated, and in the latter stage, it can provide a realistic representation of the product to be produced (Bryden, 2014, Hallgrimsson, 2012). These prototypes can be used (by both the users and the company's production capability) to test product feasibility, to enhance the chance of successful technological and product innovation. It can also be used to provide a model of the tangible outcome to convince both external investors and internal innovation stakeholders of the value of the company's innovation activities (DC, 2015).

Secondly, design gives greater meaning to products/services offered by the company through emotional and symbolic content (Verganti, 2008) drawn from new technologies to enable radical innovation (Dell'Era et al., 2010). The new message and meaning engendered by design-driven innovation occurs where technology push and design push meet in a function-message matrix (see Figure 2.20).

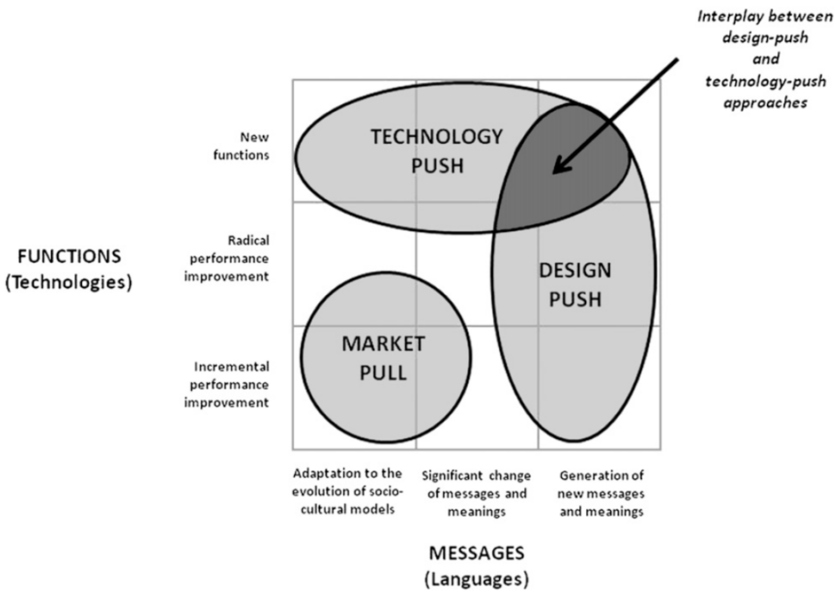


Figure 2.20: Function-message matrix for design-driven innovation (Dell'Era et al., 2010:14)

Design-driven innovation has another impact on design which differs from the user-centred approach. It allows the users to discover the meaning of a product where design provides a semantic dimension in a socio-cultural context and technology provides the functional dimension to improve customer perceptions of performance (Verganti, 2009). Design as a provider of new meaning to a product allows the design to be in early stage of the innovation process, before technology is ready for implementation. This ensures that the new language proposed by design can be implemented in products to increase the manufacturing company’s competitive advantage (Dell'Era et al., 2010, Norman and Verganti, 2014).

Thirdly, design is used as a strategic tool to enhance a company’s innovation processes. Design plays a significant role in product/service development, because the innovation process uses creativity wherever possible to turn ideas into product/service innovations (Bruce and Bessant, 2002b). Furthermore, Mozota (2006) discusses the four powers which explore the influence of design both in developing a physical, tangible product and in the management of a business. Governments are also now considering the importance of design as a strategic tool to increase industries’ global competitiveness, hoping to gain economic advantages in a highly dynamic market. The Cox report adequately demonstrates this emphasis of design use in industry (Cox, 2005). Much of The Cox Report deals with design in the UK manufacturing industry, where it found that design enhances the impact innovation has on a company. Table 2.12 shows Mozota and Cox’s view of the scope of design influence in a company.

Table 2.12: Scope of design influences within a company innovativeness.

Mozota’s four powers of design	Cox’s design influence for innovation
Design as good business	Reduced unit and labour costs
	Reduced materials and/or energy
Design as transformer	Opening new markets and an increased market share
Design as integrator	Increasing range of goods and services
	Improve production flexibility
Design as differentiator	Improved quality of goods and services
	Increased capacity

Source: Adapted from Cox, G. (2005) and Borja de Mozota, B. (2006).

Design’s overarching influence in manufacturing companies can be also found in Pugh’s theory of Total design (Pugh, 1996):

[Total design] is seen as a broadly based business activity in which specialists collaborate in the investigation of market, the selection of a project, the conception and manufacture of a product, and the provision of various kinds of user support. (Pugh, 1996:489)

Total design describes the design boundary model, predominantly developing a product in the context of manufacturing companies. However, it also provides a business design boundary which contains areas of business where design has much broader influence: development, marketing, purchasing, research, sales, finance and manufacture. As already discussed, Total innovation (NESTA, 2008b) also broadly considers innovation in manufacturing companies, including all the innovation areas discussed in the previous sections (technological, product/service, process and organisational innovation). The boundaries of Total design and Total innovation are similar in a business context. The common denominator of the two theories - provision of increased competitiveness and growth for companies - shows the close relationship between design and innovation. Harvard Business Essentials (HBE, 2003) shows a simple representative innovation process, showing almost identical processes with a typical product design process by Bruce and Cooper (1997) (Figure 2.21). Both processes involve problem identification, idea generation, development and commercialisation.

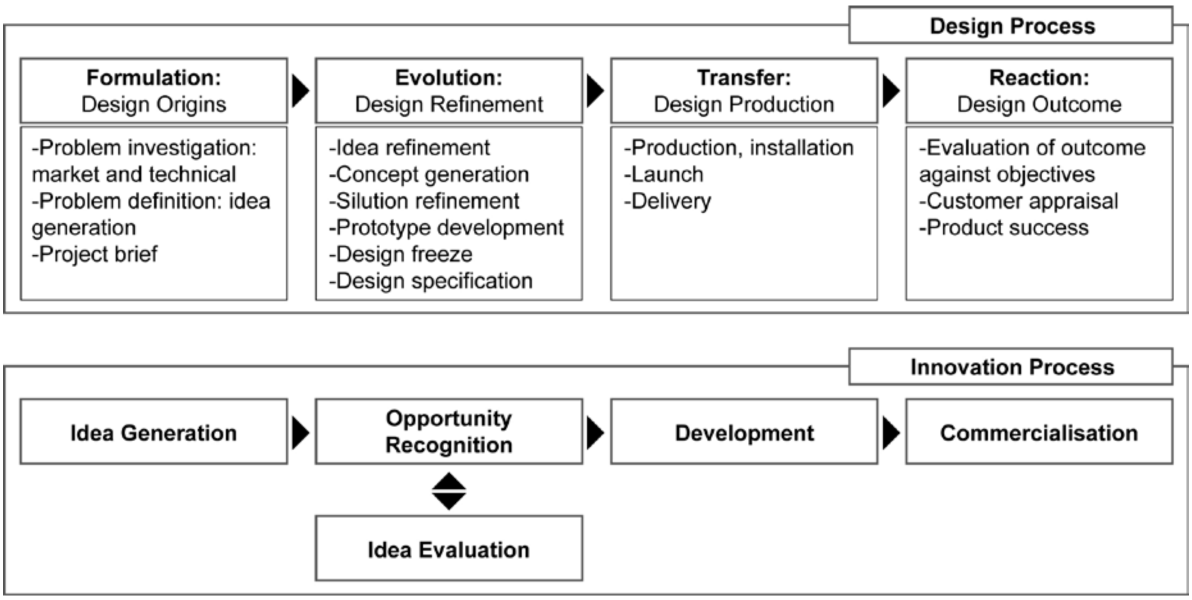


Figure 2.21: Four Stages of the Design Process (upper, adopted from Bruce and Cooper, 1997) and Innovation Process (lower, adopted from Harvard Business Essentials, 2003)

The essence of both the design and innovation processes is creativity, which takes on a critical role from initial idea generation to the development of the ideas. Another key issue of the processes is user involvement, which initiates problem/opportunity identification by either directly engaging the user in the product development process, and/or by observing them and discovering the problems/ opportunities.

2.4.2 The definition of Design Innovation

Many terms describe the influence of design for innovation, mainly ‘design-driven innovation’ (Verganti, 2009) which defines design as a source of innovation, ‘design-led innovation’ (Kyffin and Gardien, 2009) where design takes a central role in facilitating innovation (matrix), and ‘design-inspired innovation’ (Utterback et al., 2006) which is similar to design-led innovation in that it seeks balance through design between technology, the market and meanings. These terminologies broadly emphasise the important contributions of design for innovation from product creation to process development. The term ‘design innovation’ refers to a type of innovation which uses design - usually a product (Berkowitz, 1987), output of design processes (Svihla, 2010), and a contributor to innovation’s key success factors e.g. creating products which are in the ‘star’ category of BCG Matrix, and improving the new product development process (Mozota, 2003).

In this research, design innovation is a broader concept than that in current use, because of the increased recognition of a wider perspective of both design and innovation. Furthermore, design and innovation make separate – albeit highly interlinked - contributions to business success. It is thus not a type of innovation but rather how design is used to increase a company’s innovativeness. The design innovation outcome can be radical and/or incremental changes in product, service, process, organisational culture, and/or business model to increase the company’s competitiveness. In this research, the definition of design innovation is:

a creative process and its outcome which enable increased innovativeness of a company through the utilisation of the full spectrum of design including designing (action to create a product), design strategy (management of the design process), and corporate-level design thinking (the philosophy and method of design applied to business management).

2.5 Manufacturing development in the UK

Like many other developed countries, UK manufacturing industry is undergoing changes. Great stress is laid on the value of manufacturing in creating a more balanced economy and to increase national competitiveness. However, fierce global pricing competition from developing countries such as the “BRIC” nations (Brazil, Russia, India and China) is a major reason for the decline of UK manufacturing output. UK manufacturing’s current competitive edge is now recognised to be in high-value manufacturing, but the BRIC countries are rapidly catching up with the UK in this area, making competition ever more intense (BIS, 2010c). This trend was predicted by the manufacturers’ organisation, the Engineering Employers’ Federation’s (EEF) report ‘Manufacturing at the Crossroads’ (EEF, 2001), which expresses concern that if the decline of manufacturing development is not addressed, the entire UK economy will suffer the consequences, because in recent years, economic emphasis has undeniably shifted towards the service industries (WEF, 2010). The EEF followed the 2001 report in 2009 with a manifesto stating that the UK economy’s heavy reliance on financial services has made it unstable and burdened with a large deficit (EEF, 2009). Therefore, the UK government is becoming increasingly aware of the importance of manufacturing industry in sustaining the growth and increasing the competitiveness of the UK economy. The 2010 Growth Review states that manufacturing growth is a priority until 2020 (BIS, 2010b). As part of this initiative, the UK government started the ‘Make it in Great Britain’ scheme (BIS, 2011b) which seeks to modernise the old image of manufacturing, to attract investment and younger talent, and revitalise manufacturing’s earlier successes. UK manufacturing undoubtedly faces challenges in the rapidly expanding and increasingly competitive global market; the target should not be merely survival in this hostile environment but to gain economic growth and a competitive advantage on the world stage.

2.5.1 Manufacturing and economy

The UK has for decades been a strong manufacturing nation, after the industrial revolution historically made it globally one of the most powerful nations. More recently, however, the emphasis of the UK economy has shifted towards service industries, with GVA reaching 76 per cent of GDP compared to thirteen per cent in manufacturing industry (WEF, 2010).

The importance of manufacturing industry in the UK economy is still undeniable where it accounts for 50 per cent of exports with three million jobs (fourteen per cent of the workforce) and £152bn of output (Prest, 2008). With GDP growth declining in the second quarter of 2009 during the global financial crisis to as low as approximately minus six per cent (ONS, 2010), some commentators argue this may be due to the UK's over-reliance on the services industry, and that the recovery may have been slower than that of other European countries such as Germany and France (BBC, 2009). During this period when manufacturing industry was arguably the unsung hero of the UK economy, Temple (2011) states that as a nation the UK is finally recognising the importance of 'making things' and having a 'better-balanced' economy. According to the 2009 EEF report, one in seven UK manufacturing firms is beginning to bring production work closer to home again because overseas production has insufficient cost savings, slow product delivery to the market, or produces lower quality goods (BIS, 2010c). However, despite the encouraging signs for current UK manufacturing, many obstacles remain. In 2010 the UK's deficit was 13.3 per cent of GDP, proportionally the highest among the G20 countries (BBC, 2011). The UK government relies on manufacturing and exports to speed economic recovery and reduce the deficit, so it is imperative that manufacturing development is properly managed to generate the most effective output for the UK economy. This is more apparent in an era when the UK manufacturing industry is fast evolving into a 'modern manufacturing' industry, spearheading new technologies, products and ways of working (BERR, 2008). Manufacturing’s contribution in the service industry has been noticeable with fourteen per cent of the total value of service exports in 2005 resulting from manufacturing industry (BIS, 2010c), the second largest contributor after real estate, renting and business activities with 55 per cent (Neely, 2007) although they still lag behind other main competitors such as the United States and Germany.

The UK government therefore supports research into innovative manufacturing through the EPSRC (Engineering and Physical Science Research Council) with funding of £45 million in EPSRC Centres for Innovative Manufacturing, working closely with businesses to stimulate growth in the most promising and innovative areas of manufacturing research (EPSRC, 2011). The government also recognises the importance of design in manufacturing industry: the 2008 BERR (now BIS) report states that the combined strength of the creative economy and manufacturing would help secure the UK's long-term competitiveness. However, the absence of an appropriate design policy for innovative manufacturing, to foster optimum synergy between academia and businesses with design and the manufacturing industry, could result in both 'market' and 'system' failure, and 'footloose multinationals' in the area of 'creating national assets', one of the economic rationales for the national design policy published by BIS (2010a). The development and implementation of an appropriate design policy for innovative manufacturing in the UK is therefore urgent and of primary importance in order to encourage and support more comprehensive use of design in manufacturing companies.

2.5.2 UK Manufacturing sector

The UK manufacturing sector includes many industries. Companies House (CH) produces a Statistical Industry Classification (SIC) code for industry statistics (CH, 2011), with Manufacturing in Group D. The manufacturing sector contributes thirteen per cent of UK GDP, estimated at US$2.18 billion, the sixth largest in the World (WEF, 2010). The contribution of each industry towards the UK's Gross Value Added (GVA) shows that the five top industries - food, beverages and tobacco, chemicals and pharmaceuticals, publishing and printing, fabricated metal products, and machinery and equipment – together make up over half of the total manufacturing GVA (BIS, 2010c). Furthermore, the growth of manufacturing industries from 1994 to 2009 indicates that relatively high-technology industries (aircraft, rail, marine and motorcycles, chemical, pharmaceuticals, medical and precision instruments) have grown in size whereas relatively lower-technology industries (leather products, clothing, textiles) have all decreased in size (Figure 2.22).

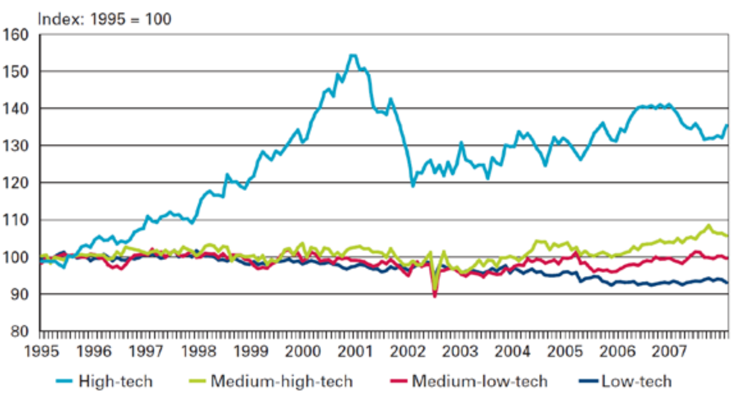


Figure 2.22: Manufacturing output in the UK(BIS, 2009:3)

Research indicates that high-technology industry competitiveness is greater than that of lower technology, mainly because of the surge of price-competitive imports from developing countries. However, Industrial System Research also states that manufacturers do not meet UK customers' needs because of their deficiency in product innovation, quality control and assurance, marketing and delivery, and after-sales service (ISR, 2003). Foresight (2013) research for the UK Government Office for Science recommends four key future manufacturing characteristics: (i) faster, more responsive and closer to customers, (ii) exposed to new market opportunities, (iii) more sustainable, and (iv) increasingly dependent on highly skilled workers. The research also considers future UK factories, identifying typical current features, and predicting likely or desired future features (see Table 2.13).

Table 2.13: UK factories of the future

UK factories of the future	Typical current features	Likely future features
Process and practices	Limited flexibility of production lines, with some potential for multi-product manufacturing	Highly capable, flexible, embedded knowledge, close customer relationships, cross sector R&D
Locations	Centralised in legacy locations, some distance from customers and suppliers	Diversity, central hubs, urban sites, distributed and mobile, home integrated design-make environments
Supply chains	Typically a mixture of global and local supply chains, not well integrated with partners with limited risk / revenue sharing	Localised & integrated 'partnering', effective use of global capabilities and adaptable logistics systems
Goals and metrics	Mostly focussed on cost, quality and delivery with less emphasis on future performance and sustainability	Speed, agility, degree of cross-region / sector collaboration, total resource efficiency, global competitiveness
Facilities	Often close to urban areas with legacy infrastructure (especially ICT) & poor sustainability performance	Innovative and customised buildings, spacious, sustainable operations, open to customers, partners and the community
Technology	Typically a focus on low risk automation and product technologies. Reliant on technology from equipment suppliers	Integrated value chain approach, digitised, Big Data enabled, additive processes and many new advanced materials
People	Typically technical and professional workers, mostly men, with processes reliant on manual intervention	Increasingly knowledge based work, continuous improvement principles, multi-skilled / gender teams
Culture	Typically a 'command and control' culture focussed on in-house knowledge, limited supply chain integration	Open, creative, networked and interactive. Integrated working principles with suppliers and research partners

Source: (Foresight, 2013:22)

Research indicates a recognition of the need for change in the UK manufacturing sector. The UK government recognises this and some leading companies are embracing the change required to not just survive but thrive in the globally competitive market (PWC, 2009). The emphasis on innovation for manufacturing is obvious because the capabilities of innovation match the requirements identified above. The following section discusses further the government and industry's emphasis on manufacturing and innovation (Section 2.5.4).

2.5.3 Manufacturing value chain

The value chain provides an overview of the accumulated build-up of activities which provides added value for customers, viewing the company as a system and a process (Needle, 2010). As manufacturing becomes more complex, it is important to understand the fundamentals of how a company operates as a system in the value chain. The initial value chain was developed by Porter (1985), showing primary and secondary activities (see Figure 2.23). Inbound logistics includes activities handling and transportation of goods from suppliers, an operation which refers to all activities which involve transforming input into the final product/service. This stage includes multiple stages in various specialist departments. Outbound logistics represents the activities which involve storing and distributing the final outcome. Marketing and sales provide the company's customer needs, and communications with potential customers, to make them aware of the product offering. Finally, the primary activity includes service to ensure the product/service works correctly.

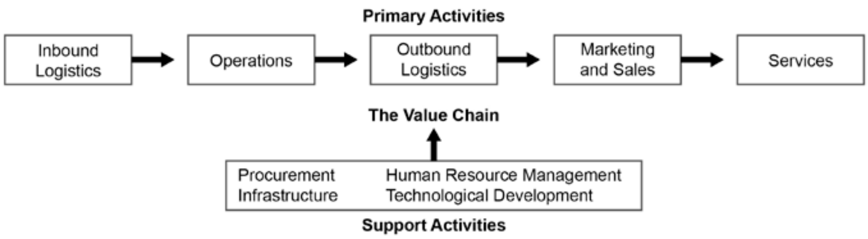


Figure 2.23: The organisational value chain (Porter, 1985)

The primary activities are supported by four supporting activities, including procurement, which is the activities involved in the acquisition of inputs or resources for the company, ideally with reliable, high-quality supplies at the best price. Human resources management includes activities to recruit, hire, train, develop, reward and dismiss personnel. Technology development is involved in all primary activities and includes the development of knowledge and dissemination of that knowledge about the equipment, hardware, software and appropriate procedures. Infrastructure is the connection between various parts of the organisation, including functions or departments (materials planning, logistics, legal, finance, public affairs etc.,). A common stereotypical perception of manufacturing is that it "only" involves production. This is referred to as small-'m' manufacturing by Poli (2001) i.e. the part of the product realisation process concerned with the physical assembly of parts. BIS (2010c) has developed a manufacturing value chain based on Porter's value chain (see Figure 2.24). This is more specific for current manufacturing and shows the activities of the entire manufacturing process.

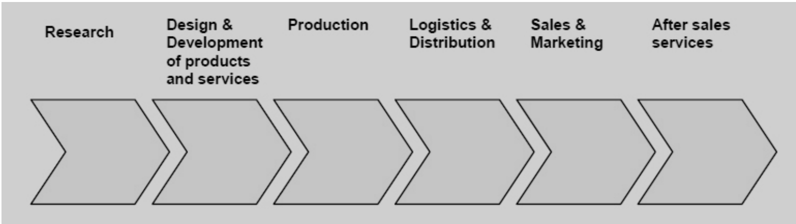


Figure 2.24: The manufacturing Value Chain (BIS, 2010c:6)

Segmentation of the 'operation' part of the original value chain into research, design and development of products/services, and production emphasises the importance of these activities in manufacturing companies. The value chain comprises a complex system of manufacturing, especially in high-technology industries (BIS, 2010c) where the supplier (Tier 1 supplier) can be involved in different production activities, with external design consultancies involved in all or part of the value chain. With globalisation, some activities may not be co-located for various reasons, including increased price competitiveness or to ascertain technical expertise and have a skilled workforce.

2.5.4 Innovative manufacturing

The UK government has identified the strengths and strategically important areas of manufacturing to be developed and supported in the future: advanced (BIS, 2009, BIS, 2010b), high-value (TSB, 2011c, TSB, 2012b) and innovative manufacturing (TSB, 2011b). BIS defines advanced manufacturing as the businesses which produce technologically complex products and processes by using a high level of design or scientific skills (BIS, 2009) with characteristics derived from BIS (2010b) and BIS (2010c):

- Intensive use of capital knowledge
- Can require long-term investment decisions to develop processes and buy equipment (which can take more than a year to manufacture)

- Uses high levels of technology and R&D and intangible investments (training, improvements to the business process etc.,) to support innovation
- Requires a flexible workforce with strong specialist skills in science, technology, engineering and mathematics and design
- Competes in international and domestic markets.

Such specialised requirements mean that advanced manufactured goods and associated services tend to be of high value. The UK Technology Strategy Board's (TSB) definition of high-value manufacturing indicates that it is the "application of leading-edge technical knowledge and expertise to the creation of products, production processes, and associated services which have strong potential to bring sustainable growth and high economic value to the UK." (TSB, 2012b:3). Advanced and high-value manufacturing both rely heavily on technological developments, but the key difference between them is that the emphasis of advanced manufacturing is on utilisation of advanced technology whereas high-value manufacturing is more focused on economic growth and value. With the emphasis on advanced and high-value manufacturing, innovation has become an important agenda for enabling manufacturing companies' success. Innovative manufacturing has enabled a new manufacturing paradigm: the traditional focus on cost and efficiency now includes innovation. However, certain conflicting preconceptions between efficiency and innovation in many areas of business (see Table 2.14) have made it harder for manufacturing companies to balance between the two main drivers for change (Trott, 2005).

Table 2.14: Efficiency verses innovation

Focus on cost and efficiency	Focus on support for innovation
Attention to detail	Bigger picture
Present	Future-oriented
Clarity and certainty	Accepting of (initial) ambiguity
Predictability	Uncertainty
Numbers driven	Visual, concept driven
Tight control	Autonomy
Repetition	Experimentation
Standards and procedures	Open-mindedness and flexibility
Failure = disaster	Failure = learning
Rational	Emotional
Preserving the status quo	Challenging the status quo

Source: (von Stamm, 2008:21)

With increasing competition from low-cost economies such as China and Eastern Europe, UK manufacturing can no longer compete on price (PWC, 2009). The UK must try to maintain the competitive advantage of the value it brings to the end-users: consumers and/or other businesses. In this hostile environment, innovation is recognised as a key differentiator to produce value-added products/service, to gain a competitive advantage. Therefore, in micro-level, the balance between efficiency driven change and innovation driven change must be achieved by UK manufacturing companies to sustain their competitiveness. In macro-level, the UK government has identified key industries such as aerospace, automotive, chemicals, pharmaceuticals and foods, to maintain or enhance the international competitiveness of UK-based manufacturing by developing 'innovative manufacturing' (TSB, 2011a).

Innovative manufacturing is difficult to categorise as there are no universally approved criteria for deciding whether the company is classified as innovative, or in a specific sector e.g. manufacturing. Laforet and Tann (2006) defined ten innovativeness indicators, mainly from the DTI/CBI reports:

- number of new product ideas a company has had in the last five years
- number of new products launched in last five years
- number of product improvements introduced in last five years
- innovation prize(s)
- when the newest product was introduced
- the percentage of sales from this product
- extent to which major customers provide specifications for new product(s)
- level of investment in office systems and technology
- level of investment in shop-floor systems and technology
- new or improved ways of working in last five years.

Innovative manufacturing also has some measureable indicators, similar to the Queen's Award for Enterprise criteria, where commercial performance of a product/service launched within three years is an important indicator. Although financial indicators provide evidence of some aspects of innovation, this does not provide definitive criteria for innovativeness as defined in this research. It should be broader, because the intention of developing innovativeness is of greater importance than previous indicators. Various manufacturing companies at different stages of innovation success should also be included as innovative. Although this maybe more difficult to define, evidence of active participation in collaborative projects with an academic organisation to increase innovativeness would be evidence of the intention and willingness of moving forward to become more innovative (Freel, 2000). Furthermore, recognition by innovation awarding bodies - The Queen's Award, The Future of Manufacturers, TMMX - would be evidence of a company's intention to become more innovative. Further exploration of innovative manufacturing will be discussed in Chapter 4 where the definition for the research is reconfirmed from the exploratory interviews.

2.6 Chapter Summary

This chapter has explored the basic principles of design, and how it has developed to become a vital strategic tool for businesses, acknowledging the complex nature of identifying the universal meaning of design, which depends heavily on the context in which the word is used. It has attempted to provide a holistic view of the expanding roles of design, including designing for a product/service, a design strategy to manage designing processes and ensure design is fully utilised by the company, and lastly of corporate design thinking where the philosophy of design is applied to manage the organisation as whole. These areas of design form the design spectrum, which shows the different attributes of design in a company. The complex meaning of innovation was also explored in this chapter. Despite innovation's complex meaning, the chapter has constructed an innovation spectrum which covers product/service, process, and organisational innovation. The relationship between design and innovation was investigated to determine how design influences innovation in a company. UK manufacturing was also explored to provide an overview of the UK manufacturing scene and the government emphasis on developing innovative manufacturing.

The next chapter explains the research methodology in depth, with an explanation of each of the methods used to fulfil the aim of the research.

Chapter 3. Research Methodology

3.1 Introduction

This chapter presents the research methodology used including its strategy and design. The research strategy explains the researcher's philosophical stance and explains the use, approach and purpose of the research. The research design is described in detail: the research process including the overview, methods for collecting and analysing data, and the justifications and background theories required to answer the research question in the previous chapter (Figure 3.1).

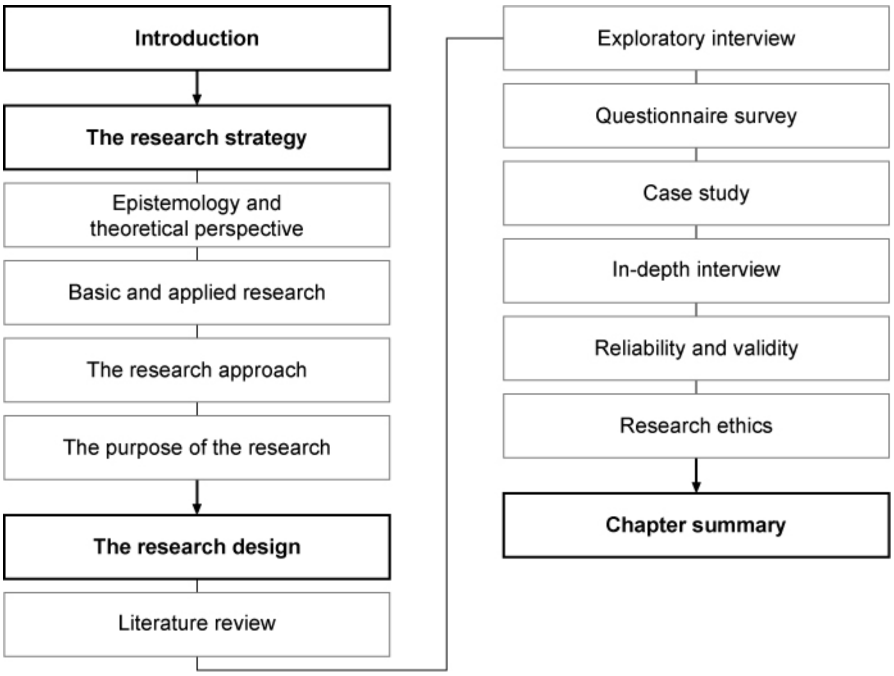


Figure 3.1: Chapter map

The research uses constructivism epistemology with an interpretivist theoretical perspective because of the constructive nature of the research, which seeks to provide a design innovation framework to further improve the innovativeness of UK innovative manufacturing. The research also has certain applied research characteristics, specifically action research. The principle of inductive research is also used, although some elements of the research are inherently deductive in nature - e.g. the framework evaluation - which is typical of much modern research. The purpose of the research is thus explorative in principle, using studies, which require elements of descriptive enquiry to evaluate the theories generated during the research process.

The research is designed to provide a rigorous process drawing on the grounded theory approach, where theories generated by the data are analysed to form new knowledge for academia and for the real world (innovative manufacturing and design industry). Several methods are used to achieve the research aim, including: (i) literature reviews to understand the context of design, innovation and manufacturing businesses, and current design innovation theories, (ii) exploratory interviews to explore the context of innovative manufacturing, (iii) exploratory questionnaire surveys to understand the innovative manufacturing context and more importantly, the perception, role and utilisation of design in innovative manufacturing, (iv) case studies to provide a real-life picture of the implications of the design innovation spectrum, and (v) a series of in-depth expert interviews to gain deeper understanding of the context, and to evaluate and generate design innovation characteristics which are fundamental to generating the design innovation framework. These methods are designed both to provide insight into the phenomenon and to evaluate the validity of the research, using triangulation of methods and data where possible to ensure reliability.

3.2 The research strategy

Research comprises a range of activities which attempt to answer the researcher's enquiry (Silverman, 2010). In order to achieve the research goal, one must first understand the framework in which the action takes place: the framework is referred as the research strategy (Patton, 1990). The researcher's fundamental understanding and the nature of the enquiry are key to constructing the strategy, and selecting a technique appropriate for the study (Patton, 1990, Crotty, 1998), so this section discusses the research strategy from the epistemological stance to the proposed purpose of the research.

3.2.1 Epistemology and theoretical perspective

This research creates theoretical and practical knowledge of complex objects (i.e. design, innovation, and innovative manufacturing), so the epistemology is unlikely to rely exclusively on one particular stance. However, the research principally employs constructivism epistemology, as the meaning (further improvements in innovativeness of innovative manufacturing companies) is constructed separately from the interaction between the subject (the researcher) and the objects (design, innovation and manufacturing companies). The researcher thus acts as an agent who interprets information from both design innovation and the manufacturing context, and provides objective theory to be implemented by the object (Guba, 1990). The theoretical perspective of the research is interpretivism because of its close link with constructivism (Gray, 2009), but more importantly the research adopts the philosophy of symbolic interactionism in constructing meanings through continuous integrations with the object (Crotty, 1998, Berg and Lune, 2012).

Epistemology is a philosophical approach to knowledge which explains and justifies the assumption of a researcher's knowledge to build appropriate theoretical perspectives and methodology (Crotty, 1998, Miller and Brewer, 2003, Easterby-Smith et al., 2008). It is also described as a worldview (Guba, 1990, Creswell, 2009), paradigms (Guba and Lincoln, 1994) or broadly conceived research methodologies (Neuman, 2003). Epistemology is the first consideration a researcher should explore, as their epistemological stance will influence theoretical perspectives and subsequent methodology and data-gathering methods (Gray, 2009).

Although various authors define the boundaries of the concept of epistemology differently, and even interlink ontology and theoretical perspective together (Creswell, 2009), objectivism, constructivism and subjectivism are the main epistemological stances (Crotty, 1998). Objectivism describes meaning independently from consciousness (subject), that the truth is discovered from something (the object). In other words, the truth is out there and we need to discover it. In contrast, constructivist epistemology is where the meaning is constructed from engagement of our consciousness (the subject) with something (the object). The meaning exists only through this interaction. In subjectivism, the meaning is imposed by a subject on an object. The meaning is not created but imported from anything other than an interaction between subject and object, in contrast with constructivism.

3.2.2 Basic and applied research

Research has two main uses (Neuman, 2003): “basic research” which focuses purely on scientific and academic knowledge creation which advances general knowledge, and “applied research” which aspires to solve specific problems with pragmatic orientation. The current research aims to create a design innovation framework for UK innovative manufacturing companies as a tool to increase innovativeness, to enhance competitiveness and growth potential. The research, which addresses the problem of the limited perspective and the under-utilisation of design in innovative manufacturing, is therefore inherently geared towards applied research.

The characteristics of applied research are followed in this research (Patton, 1990, Neuman, 2003) including: (i) raising consciousness or increasing awareness of issues, by providing a comprehensive overview of design innovation in a business context (the design innovation spectrum), and underlying actions, effects and benefits of design innovation characteristics (design innovation framework) in innovative manufacturing companies in the UK, and (ii) relating to a plan or programme of actions, by recommending an implementation process with scenarios for innovative manufacturing companies as well as well as the design innovation consultancies to optimise the use of design innovation framework.

3.2.3 The research approach

The research adopts the principle of the inductive approach where information on expanding perceptions and the role of design and innovation in businesses, and the context of UK innovative manufacturing, are gathered to formulate and recommend a design innovation framework and its implementation in UK innovative manufacturing companies. However, in the wider research context, the theories produced from different phases of the research undergo continuous evaluation to ensure the theoretical concepts are feasible and therefore valid in the context of the study (i.e. design innovation and innovative manufacturing). Hence, there are elements of the deductive approach a combination of approaches typically found in researches for modern problems (Gray, 2009, Robson, 2011) as the network of contributors on which the research draws is complex and requires a combination of both approaches.

Induction and deduction are the two main reasoning approaches in a research, depending on the researcher's thinking process or the research project (Dewey, 1998, Gray, 2009). The inductive process requires data collection and analysis to discover patterns in order to ascertain generalisations, relationships and theories. Induction requires a critical approach, to identify emerging patterns and their subsequent significance to build a theory which is relevant to the context of study (Crotty, 1998, Bryman, 2008). Conversely, the main purpose of the deductive approach is to test a hypothesis or theory, which enables the research to confirm the concept. This approach requires the theory or concept to be measurable to enable the research to either prove or disprove the initial hypothesis (Gray, 2009). The nature of the two approaches means that inductive studies tend to use qualitative methods - interviews, observations, and case studies (Creswell, 2009) - whereas deductive studies are likely to use quantitative methods such as questionnaire surveys (Kumar, 2011).

3.2.4 The purpose of the research

The research is largely 'exploratory' because the research primarily asks 'what?' questions and seeks to create a set of categories (design innovation characteristics) in order to provide a detailed picture of design innovation in innovative manufacturing in the UK as explained by Neuman (2003). However, certain elements of the research may cross categorisation boundaries e.g. series of evaluation studies seeks to test the theory (i.e. the design innovation spectrum and the design innovation framework) for classifying categories and discover feasibility of the theories in commercial environment which is part of a descriptive research. This is often the case when the research attempts to answer several questions (Gray, 2009).

The purpose of conducting research can be divided into three main categories (Neuman, 2003, Robson, 2011): exploratory, descriptive and explanatory (Table 3.1). The exploratory enquiry seeks to answer "what?" questions, to explore a largely unexplored social phenomenon (Saunders et al., 2009), so qualitative techniques are often used for an exploratory enquiry (Neuman, 2003).

Table 3.1: Purpose of research

Exploratory	Descriptive	Explanatory
• Become familiar with the basic facts, settings, and concerns. • Create a general mental picture of conditions. • Formulate and focus questions for future research. • Generate new ideas, conjectures, or hypothesis. • Determine the feasibility of conducting the research. • Develop techniques for measuring and locating future data.	• Provide a detailed, highly accurate picture. • Locate new data that contradict past data. • Create a set of categories or classify types. • Clarify a sequence of steps or stages. • Document a causal process or mechanism. • Report on the background or context of a situation.	• Test a theory's predictions or principle. • Elaborate and enrich a theory's explanation. • Extend a theory to new issues or topics. • Support or refute an explanation or prediction. • Link issues or topics with a general principle. • Determine which of several explanations is best.

Source: (Neuman, 2003:15)

Descriptive research aims to describe the relationship between a situation, person, or event to provide an overview of a phenomenon (Gray, 2009), essentially answering "how?" and "who?" questions (Neuman, 2003). Finally, the purpose of explanatory research is to explain the source of a social behaviour or phenomenon (Neuman, 2003, Yin, 2009). It is conducted to answer the "why?" question where the distinction between descriptive and explanatory can be used also to describe qualitative and quantitative research respectively (Gray, 2009).

3.3 Research design

Research design is fundamentally a sequence of answering the research question by selecting and collecting relevant data and critically analysing them to draw a conclusion (Neuman, 2003, Yates, 2004, Gray, 2009, Yin, 2009, Berg and Lune, 2012). It is used to identify potential flaws in answering the research question (Yin, 2009), and specify how the research will be conducted (Berg and Lune, 2012). Another consideration the researcher must consider when designing the research is the duration of the research, bearing in mind that in most qualitative research data collection continues while previous data is analysed (Richards and Morse, 2013). However, as with any good design, it is inevitable that iterations and improvements will be made during the course of the research, because experience and knowledge gained whilst conducting the research surpasses that anticipated by the initial research design. Some alterations were made as this research progressed, but the fundamental research question remained the same throughout. The overview of the research design is shown in Figure 3.2.

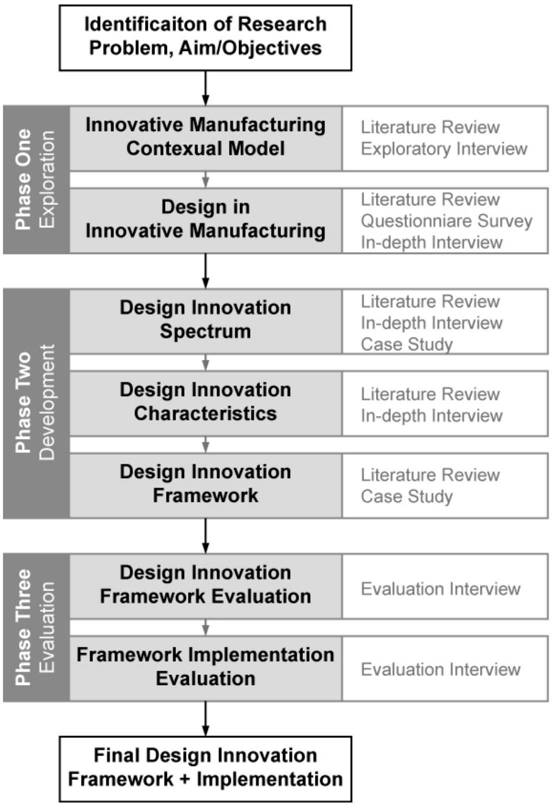


Figure 3.2: Overview of the research design

The first phase of the research explores the meaning of innovative manufacturing in relation to advanced and high-value manufacturing, which are regarded as important strategic areas of UK manufacturing. The perception, role and utilisation of design in the innovative manufacturing context were then explored to identify the key issues of design in UK innovative manufacturing. This phase of the research was a part of a BRIEF (Brunel Research Initiative & Enterprise Fund) project called ‘Design Policy for Innovative Manufacturing in the UK’ (Principal Investigator - Dr Youngok Choi), which aims to create an agenda for developing a national design policy. The researcher played a significant part in planning, gathering and analysing the data necessary to achieve that aim. It was collaborative research with Lancaster University, and project meetings were held throughout the research phase with academics from Brunel University London and Lancaster University to provide ongoing critique, evaluations and developments.

In this phase, both qualitative and quantitative methods were used, including exploratory interview, questionnaire survey, and in-depth interview. The exploratory interview was conducted with four manufacturing academics who had a significant interest in the development of manufacturing as an industry and special technical researches to enhance the advancement of manufacturing. This was followed by a questionnaire survey with innovative manufacturing companies, as defined in the literature review. Some forty-eight responses were collected which enriched the understanding of the context. A series of in-depth interviews was conducted with eleven manufacturing industry experts to gain deeper insight into the use of design in innovative manufacturing companies to further identify issues about the utilisation of wider areas of design. This phase employed mixed methods to ensure that the data and subsequent analysis are valuable in constructing an insightful overview of the context of design in UK innovative manufacturing. The main outcome of the first phase was evaluated by presenting at the DMI research conference, 'Leading Innovation Through Design', Boston in August 2012 (Na and Choi, 2012). The audience of academics and practitioners of design management from all over the world provided valuable feedback which helped to better construct the next phase of the research.

The second research phase went on to develop: (i) a design innovation spectrum which aims to provide an overview of the inter-relationship between design and innovation in a business context, (ii) the design innovation characteristics which comprehensively represent the actions, effects and benefits of design innovation for innovative manufacturing companies, and (iii) the design innovation framework and subsequent implementations to illustrate how design innovation benefits companies by developing different areas of innovation, leading to subsequent growth and increased competitiveness for innovative manufacturing companies. This phase used qualitative in-depth interviews and case study to gain specific insights from the experts in the field of study and to relate it to real-life situations. The eleven design innovation experts - drawn from design consultancies, a design NGO, and a governmental innovation support organisation for manufacturing companies - first evaluated the design innovation spectrum created as part of Development 1. They then provided insights about design innovation actions and their subsequent effects on innovative manufacturing companies, from their extensive experience of working for and with the innovative manufacturing companies to help construct design innovation characteristics (Development 2). The first part of the in-depth interviews with eleven manufacturing industry experts provided data about current issues in the utilisation of design in innovative manufacturing companies for the first phase (exploration). In the second part of the interview they, like design innovation experts, explained the possible actions and effects of design innovation for innovative manufacturing companies, which also contributed to formulating the design innovation characteristics (Development 2). The forty-six innovative manufacturing companies were investigated as part of the case study, which provided real-life examples of using aspects of the design innovation spectrum (Development 1) and their possible effects. The case study was then used to build three scenarios of possible innovative manufacturing company situations which could use the design innovation framework, which formed part of the framework implementation process (Development 3).

The third phase evaluated the design innovation framework and its subsequent implementation, using the qualitative in-depth interview method. The interviews were conducted with ten experts in the field of design innovation and innovative manufacturing. The design innovation framework booklet was produced and distributed for the interviewees to review prior to the interview and evaluated the framework and implementations at the interview to provide insights about viability, feasibility, and usability. The interview results were then used to finalise the framework and implementation process as a research recommendation.

3.3.1 Literature review

This research uses literature review extensively; it is used to understand the existing theory and critically review, analyse and synthesise that body of knowledge mainly in the areas of (i) expanding meaning and practice of design and innovation in businesses, (ii) manufacturing and its relevance to the UK, (iii) an overview of business operations, (iv) the relationship between design, innovation and manufacturing in the UK. The goal of the first area is to obtain a holistic perspective to better understand the overall benefits. Each discipline (design and innovation) is then categorised in order to compare and generalise the areas of design and innovation in manufacturing companies. The second area of literature review is of manufacturing, to generate contextual issues in manufacturing development and their importance, as it has become a critical issue for the UK and other developed countries to increase global competitiveness. Thirdly, literature about business structure and operation was studied to create a firm anchor for the complex - and sometimes contradictory - theories of design and innovation.

Literature review is defined as the selection, critical review, analysis and synthesis of both published and unpublished documents which enable the researcher to gain a comprehensive current overview of information, ideas, data and evidences on the topic of enquiry (Hart, 1998, Neuman, 2003, Silverman, 2010). The purpose of the literature review (Neuman, 2003) is to: (i) narrow down the broad topic, (ii) identify the "state of knowledge" on a topic, (iii) stimulate the researcher's creativity and curiosity, and (iv) provide good examples of other studies for the methodology and presentation of research. Gray (2009) adds that it also provides up-to-date understanding, and identifies significant issues, particularly gaps in current knowledge. In a research report, the literature review is used to (i) dispel myths, (ii) explain competing conceptual frameworks, (iii) clarify the focus of the researcher's work, and (iv) justify assumptions (Berg and Lune, 2012). Information can be obtained from various sources: periodicals, scholarly journals, newspapers magazines, television, radio broadcasts, textbooks, encyclopaedias etc., but it is essential for researchers to distinguish the relevance, balance of opinions, and purpose of the literature (i.e. intended audience) for it to be used as a valid source of information (Neuman, 2003).

3.3.2 Exploratory interview

In the early stages of a research, it is important for the researcher to be familiar with the context in which the exploration takes place (Bryman, 2008). Interviews complement the literature review and provide a means to explore and develop an in-depth understanding of the topic (more explanation on interview is expanded on later in this chapter), and this research uses various interviews to explore design, innovation and manufacturing issues. This includes several non-structured interviews with experts in the field of design, innovation and manufacturing at research conferences, trade shows, events organised by both governmental organisations and NGOs etc., Exploratory interviews were also conducted with manufacturing academics to provide deeper understanding of innovative manufacturing in the context of the UK manufacturing sector, and its relationship to advanced and high-value manufacturing which are, as the literature review identified, the three strategically important areas of UK manufacturing. The interview was conducted using the face-to-face, semi-structured method in order to construct an overview of the significance of innovative manufacturing for the manufacturing industry itself. The academics were specifically chosen to provide insight into both academic and industry perspectives, as they have both extensive academic research experience and of working in and/or collaborating with the manufacturing industry. Purposive sampling was therefore used to obtain the most relevant overview of broader manufacturing. Table 3.2 shows the interviewee profiles.

Table 3.2: Exploratory interviewee profile

Interviewee	Title	Affiliation	Profile/Expertise
MA1	Lecturer	Advanced/Innovative Manufacturing	Co-ordinator of an innovative manufacturing group in a university, extensive industry experience and an interest in cultivating innovation in manufacturing industry.
MA2	Director	EPSRC Innovative Manufacturing Centre	Application of rigorous scientific and technological research in manufacturing industry.
MA3	Head of	AMEE (Advanced Manufacturing Enterprise Engineering)	Advanced manufacturing and the fundamentals of manufacturing systems, and extensive collaborative research in manufacturing industry.
MA4	Senior Lecturer	Engineering Design, Manufacturing Engineering	Chairman of the UK Design for Manufacture (DFM) BSI group, and made a significant contribution to creating BSI 8887 and ISO 9000

Drawing on the literature review, various context models of innovative manufacturing were constructed prior to the interviews to aid the interview process, in an attempt to visualise the definition in relation to advanced and high-value manufacturing. The figures were shown to each academic for comment, seeking guidance to contextualise the research's definition of innovative manufacturing in UK manufacturing industry (see Appendix A). The key topics discussed were:

- the expert's definition of advanced/high-value/innovative manufacturing
- the meaning and value of the innovative manufacturing sector
- the key benefit of the expert's research for innovative manufacturing and for general manufacturing in the UK

- comments on the contextual manufacturing models presented, and
- the role of design in innovative manufacturing.

Each interview was approximately sixty minutes. The researcher noted key points and a report was written soon after each interview to ensure that no details were missed. Writing or drawing on the models was encouraged and the interviewees' notes and drawings on the initial models were used to reinforce the interviewees' opinions about the relationship between advanced, high-value and innovative manufacturing. The results were then used to construct a contextual model of innovative manufacturing. This took several iterations, using evaluation conducted with academics from manufacturing and design management (the BRIEF project team). The final model was constructed to illustrate the relationship between innovative, advanced and high-value manufacturing to add to the "richness" to the research (Fielding, 2012).

The meaning of advanced and high-value manufacturing was then expanded to construct a generalised innovative manufacturing model. The generalisation process was conducted using horizontal evaluation (Thiele et al., 2007) which combines self-assessment and external peer evaluation. Therefore, the innovative manufacturing model was analysed by the researcher first to identify commonalities between the meaning of each influence (i.e. advanced and high-value manufacturing) in the wider context of innovation and business values. This was followed by the peer meeting with four PhD researchers in the areas of manufacturing and design management to evaluate whether the concept could be generalised. The generalised context model was then constructed to provide an overview of how innovative manufacturing influences different types of innovation and subsequent business development (Chapter 4). The interview findings also provided a basis for constructing the questionnaire survey which explores perceptions of design in UK innovative manufacturing companies.

3.3.3 Questionnaire survey

A questionnaire survey was undertaken for this research with innovative manufacturing companies in the UK, to explore the perception of design, innovation and manufacturing, and their use of design. The "descriptive" survey spurred further in-depth research to investigate the same topics using the in-depth interview, to form a triangulation of methods exploring the perception of design and its role in innovative manufacturing companies.

A survey is among the most popular methods used by commercial, government and private organisations (Yates, 2004, Gray, 2009). It can be systematic "descriptive" data collection which provides participants' perspectives, or "analytical" which attempts to prove or validate a theory (Gray, 2009, Henn et al., 2009). The descriptive survey answers 'what?' questions, the enquirer asking questions based on sound theory to explore the situation and thereby inspire further theory construction or problem identification, leading to appropriate actions (De Vaus, 2002). It is used to gather information about people's opinions and perspectives, with less concern for numerical precision (Fowler, 2002). The analytical survey uses variables to determine the relationship, which can be proven with statistical precisions (Gray, 2009). The advantage of using a survey varies greatly depending on the nature of the research. However, the typical advantages and disadvantages (Gillham, 2008) are shown in Table 3.3.

Table 3.3: Advantages and disadvantages of a questionnaire

Advantages	Disadvantages
• Low cost in time and money • Easy to get information from many people very quickly • Respondents can complete the questionnaire when it suits them • Analysis of answers to closed questions is straightforward • Less pressure for an immediate response • Respondents' anonymity • Lack of interviewer bias • Standardisation of questions (but true structured interviews) • Can provide suggestive data for testing a hypothesis.	• Problem of data quality (questionable accuracy) • Typically low response rate unless sample is captive • Problem of motivating respondents • The need for brevity and relatively simple questions • Misunderstandings cannot be corrected • Seeks information only by asking questions • Assumes respondents have answers available in an organised fashion • Lack of control over order and context of answering questions • Question wording can influence the answers • Most people talk more easily than they write • Impossible to check how honest the answers are • Respondent uncertainty as to what happens to data.

Source: Adapted from Gillham (2008)

Despite the disadvantages listed above, the survey is the most appropriate method for this particular study to explore the broad perceptions of innovative manufacturing companies. The survey method must be systematically designed and executed to explore specific issues. Yates (2004) suggests that the researcher must consider: (i) measurement, (ii) sampling, and (iii) questionnaire design and administration. Measurement is the operationalisation of the concept being tested. In social research, the concept may be abstract, so the "fuzziness" of the concept must be clarified. This is less relevant here, as the survey was not conducted to prove a hypothesis. However, the concept remains valid because the wording of the self-filled questionnaire can be misleading, and may not present accurate data (Bryman, 2008). The other key aspects under consideration - sampling and questionnaire design and distribution - will be discussed in the following sections.

3.3.3.1 Sampling

Of the 4.6 million UK private sector businesses, some 274,000 are private manufacturing companies (BIS, 2013). It is difficult, however, to identify from research which manufacturing companies are innovative manufacturing companies, unless individual companies are cross-referenced for their involvement in external collaboration or winning awards The only viable choice for sampling the survey was therefore non-probability sampling, on the understanding that population generalisation has its limitations (Henry, 1990) because of the unknown quantity of the population and the exploratory nature of the study. However, in the non-probability sampling a purposive sampling technique was used to enhance representativeness, with advice from academic experts in the manufacturing field (Matthews and Ross, 2010). Furthermore, a triangulation of methods was used to enhance the validity of the outcome (Denzin, 1978), and to gain deeper understanding of the phenomenon (Bryman, 2008, Creswell, 2009). The samples selection follows the criteria for innovative manufacturing companies as described in Section 2.5.4. The criteria identified suggests that the company must demonstrate its continuing commitment to innovation by either actively collaborating with external organisations to enhance their innovativeness and/or demonstrate market success with new or improved products and/or by winning recognised innovation-related awards.

3.3.3.2 Questionnaire design

A theoretical context was constructed for the survey, using the literature reviews and exploratory interviews to produce meaningful data which demonstrate the innovative manufacturing companies' (i) characteristics including main markets and their strength, (ii) perception of design and innovative manufacturing, and (iii) to identify the use of design in innovative manufacturing.

The first part of the questionnaire asked for information about the respondents - their job title and role, and their company sector, size, business maturity (years in operation) - to broadly identify the population of the survey respondents. The main part asked questions which reflected the study objectives. The questionnaire was constructed using both closed and open questions, considering the advantages and disadvantages of both question types (Neuman, 2003, Bryman, 2008). The advantages of the closed question include easy and quick for respondents to answer, answers are easy to code or statistically analyse, the response choices can clarify the question, and irrelevant or confused responses are reduced. However, there are disadvantages: respondents' frustration if the choices do not include the desired answer, suggesting ideas the respondent may not have considered, providing a simplistic response to complex issues, and forcing respondents to make choices they would not make in the real world. The advantages of open questions include that respondents can answer in detail, unexpected (positive) findings can be discovered, revealing the respondent's logic, thinking process and frame of reference. Some disadvantages include the difficulty of controlling the level of detail in answers for different questions and respondents, statistical comparison can be difficult, answers can be open to interpretation, and time-consuming. The questions for this study therefore include elements of both closed and open question format, providing quick, easy to answer questions but with maximum flexibility of answering and an 'other' selection for the respondents to create an answer if their view is not among the available choices. Furthermore, comment sections are provided at the end of the questionnaire to accommodate respondents' thoughts and suggestions about the research.

The questionnaire was designed to accommodate the possible samples, typically the senior managers or employees who can provide an overview of the operations of a business and information about the use of design within the company as whole. The survey had to be brief and precise, as the respondents were likely to be pressed for time (Hickman and Longman, 1994), so on-line questionnaire tools were used, to enable prospective respondents to access and complete the questionnaire with minimum effort (Henn et al., 2009), and to produce a better return (Mehta and Sivadas, 1995, Stanton, 1998) than when using a paper questionnaire by post. The on-line questionnaire can also produce a series of 'if'/'then' logic questions without any extra effort from the respondents such as "if yes, please go to question X” or “if no, please turn to page X”, thereby further simplifying completion of the questionnaire.

Prior to distribution, the survey was tested through several iterations with experienced academics in both design management and manufacturing to ensure that the meaning of the wordings could be correctly interpreted by prospective respondents, and that the overall questionnaire structure is logical and easy to follow (Henn et al., 2009). The questionnaire was also evaluated with the academics to ensure the questions are objective and non-persuasive, and closely follows the aim and context of the study (Fowler, 2002). The questionnaire was then pre-tested with two managing directors of UK innovative manufacturing companies to provide suggestions for improvements which were included to create the final questionnaire for wider distribution, as suggested by Bryman (2008), to ensure that potential problems were eliminated (see Appendix B).

3.3.3.3 Distribution, collection and data analysis

The survey distribution was then conducted in three ways. Firstly, the researcher identified all organisations in the EPSRC Centre for Innovative Manufacturing which collaborate with UK universities, some 130 companies and organisations. These were then reduced to 68, by studying the project websites and reports of all the private manufacturing companies operational in the UK which have direct involvement for innovation development. These companies were then contacted individually by the researcher, first using the general enquiry e-mail address or the top-level manager’s (e.g. Managing Director or CEO), if available in the public domain, briefly explaining the research and attaching an on-line questionnaire link. The second means of distribution was through the BRIEF project partner at Lancaster University, with an extensive list of 267 external collaborative companies involved currently or in the past in the ‘Product Development Unit’ projects, as all these companies satisfy the criteria for ‘external collaboration’ to increase innovativeness, in this case, particularly product innovation. Similarly, the third distribution channel was through Brunel University London’s ‘Innovative Collaboration Research Network’, through which 35 manufacturing companies were contacted. Although three different distribution channels were used, the principle of sampling and contact method and procedures were kept constant.

A total of 370 requests were sent, 53 returned the questionnaire, of which five were considered invalid (three incomplete questionnaires and two inappropriate companies i.e. retail sector), resulting in the collection of 48 valid responses, indicating a 13% return rate overall. It was relatively simple to analyse the questionnaire survey data to determine the broad perspective of the innovative manufacturing companies. As the survey was descriptive, a simple frequency distribution analysis method was used (Neuman, 2003) and subsequent histograms of the results explain the distribution percentages.

3.3.4 Case study

This research employs the case study method to: (i) identify the link between the design innovation spectrum and its practical implications and (ii) obtain a perspective on real-life excellence in design innovation. Innovative manufacturing companies in the design and innovation context were studied using the multiple-case design, to provide a comprehensive insight into the implications of design innovation in UK manufacturing companies.

Yin (2009) describes a case study as an empirical inquiry where an in-depth investigation of a contemporary phenomenon is conducted in a real-life context. The 'case' may be an organisation, a life, a family or a community (Bryman, 2008), and usually takes the form of qualitative research (Creswell, 2009) without limiting the number of variables and evidence sources. A case study is used when there is no clear evidence of a distinction between the phenomenon which is of particular interest for this research: relating the theory of the design innovation spectrum to examples of real-life development of design innovation in UK innovative manufacturing companies. Stake lists three types of case studies (Stake, 1995): intrinsic, instrumental, and collective. The intrinsic case study is used when the phenomenon is in a unique situation and the inquirer wishes to investigate the subject, consequently with limited transferability. The instrumental case study is concerned with understanding a particular situation or phenomenon to obtain insights. Finally, the third type is the collective case study which examines more than one case to obtain collective understanding of the phenomenon. The current research uses a combination of instrumental and collective case study, to understand the implications of using design innovation with several innovative manufacturing companies.

3.3.4.1 Sampling

Silverman (2010) argues that case studies, although within the confines of limited integration, can be used to identify particular patterns of social organisation (in this study, innovative manufacturing companies). There are two different case study design: single- and multiple-case designs (Yin, 2009). The single-case is used when there is an extreme or unique case or when it can be a representative case in given circumstances. It is also useful in a longitudinal situation, to study a case at different points in time. The multiple-case design, as the name suggests, uses more than one case. It is sometimes referred to in the field of comparative study (Eckstein, 1975) because it can use multiple cases to examine a phenomenon or situation. Multi-case design is therefore regarded as yielding more robust outcomes (Herriott and Firestone, 1983, Yin, 2009). However, it can reduce the intensity of the research, and the emphasis of the study can be easily shifted (Gerring, 2007). Furthermore, depending on the number of enquiries, it can be time-intensive (Yin, 2009).

This study uses the multi-case design for its ability to explain the phenomenon in the broader context of innovative manufacturing rather than concentrating on an intensive single case study. In order to select innovative manufacturing companies, the criteria identified in Section 2.5.4 were used, particularly with the innovation award-winning companies, because it provides the definite result of using design innovation to win the award. Four main awards were examined: two are design-oriented (DME Awards, dba Design Effectiveness Awards), the other two are innovation-based (Queen's Awards for Enterprise-innovation, The Manufacturer MX Awards). The awards were chosen for their rigorous judging criteria and recognisability among design and manufacturing professionals and academics, after conducting numerous conversational interviews at design and manufacturing conferences (among them, the DMI Design Management research conference 'Leading innovation by Design', 2012, MACH 2012, DMI Network night, 2013, The Design Council Summit 'Leading Business by Design', 2014, TSB High-value manufacturing support event, 2014, Future of innovative manufacturing conference, 2014). Case studies suggested by The Design Council were also included because they provide reliable information about companies which have achieved successful innovation through using design. The award profiles can be found in the Table 3.4.

Table 3.4: Profile of the awards

Orientation	Award	Main focus	Assessment
Design	DME Award	Management of design in both public and private sector organisations. Focuses on ongoing process, business decisions and strategies to enable innovation. The award recognises the design in a holistic manner which can be applied in all levels of organisations.	Five jury members judge a poster submitted by the applicant organisations.
	dba Design Effectiveness Award	The main criteria for the award are return of investment by using well-executed design and/or design strategy with tangible and measurable effect on the success of businesses. It focuses on collaboration between external design consultants. The award takes the view that design provides financial value for the companies and should therefore be seen as a good investment.	Entry only by client and designer together and judged by business leaders.
Innovation and manufacturing	Queen's Award for Enterprise-Innovation	Innovation in terms of invention, design or production goods, performance of service, marketing and distribution, and after-sale support of goods or service must be demonstrated with two years of outstanding commercial success and five years of continuous commercial success.	Self-assessment questionnaire with external accountant's certificate.
	The Manufacturer MX Award	Thirteen broad categories covering the breadth of the industry recognise outstanding performance. The innovation and design category considers the development of innovation in a company and how the culture of innovation has generated successfully improved products, service and process.	Maturity level questionnaire and supporting statement, half-day visit to the site, presentation and Q&A.

Source: (dba, 2014, DME, 2014, GOV.UK, 2014, TMMX, 2014)

To ensure the validity of the case used in the study framework, the winners were selected if they were: (i) manufacturing companies operating in the UK, (ii) showcased (usually on the winner's story section) by the awarding body, and (iii) have readily available secondary information sources other than the company website. The second category was devised to identify the rationale for winning the award and form an unbiased opinion on the successful implementation of design innovation in the company. The third category was also included to ensure objectivity of the data collected from the secondary source. As such, the number of valid cases was reduced to five from the DME Award, eleven from dba Design Effectiveness Award, twenty-one from the Queen's Award for Enterprise, and three from The Manufacturer MX Award. The Design Council's designing demand programme was also studied with same criteria, which included 6 manufacturing companies. Some forty-six innovative manufacturing companies were thus selected for the case study: twenty-two which won design-oriented awards or featured in The Design Council's case study, and twenty-four which won innovation and manufacturing-oriented awards.

3.3.4.2 Data collection

The case study uses secondary documents as the main source of information to construct a broader picture of the use of design in UK innovative manufacturing companies. Another advantage of using the documents is its stability, especially for published materials. They can be important evidence in determining the perspectives of a certain event, sometimes more accurately than the primary research data (Crawford, 1997) in a marketing research context. Furthermore, the promotional materials, in contrast with the bias nature and lack of representativeness of a whole industry (Bernard and Ryan, 2010), provide an accurate picture of a company's values and emphasis, providing documents to achieve the 'objective' of promoting the company. If these objectives are vicariously observed, the documents can be correctly and critically interpreted, avoiding some of the disadvantages shown in Table 3.5.

Table 3.5: Six source of evidence: strength and weaknesses

Source of evidence	Strength	Weakness
Documentation	• Stable - can review repeatedly • Unobtrusive - not created as a result of the case study • Exact - contains exact name, references, and details of an event • Broad coverage - long span of time, many events, and many settings	• Retrievability - can be difficult to find • Biased selectivity, if collection is incomplete • Reporting bias - reflects (unknown) bias of author • Access - may be deliberately withheld
Archival records	• As above and, • Precise and usually quantitative	• As above and, • Accessibility due to privacy reasons
Interviews	• Targeted - focuses directly on research topic • Insightful - provides perceived causal inferences and explanations	• Bias due to poorly articulated questions • Response bias • Inaccuracies due to poor recall • Reflexivity - interviewee gives what interviewer wants to hear
Direct observations	• Reality - covers events in real time • Contextual-covers context of "case"	• Time-consuming • Selectivity - broad coverage difficult without a team of observers • Reflexivity - event may proceed differently because it is being observed • Cost - hours needed by human observers.

Participant observation	• As above and, • Insightful into interpersonal behaviour and motives	• As above and, • Bias due to participant-observer's manipulation of events
Physical artefacts	• Insightful into cultural features • Insightful into technical operations.	• Selectivity • Availability.

Source: (Yin, 2009: 102)

The case study data were collected with an explicit data collection plan (Yin, 2009) because the documents can be collected from a variety of sources. The samples (innovative manufacturing companies) identified in the previous section are studied for their history, culture, processes (both innovative and business management), philosophy of the top-level manager (CEO, managing directors etc.), and success stories of design innovation (problem-solving) in order to understand and predict the use of areas of the design innovation spectrum. The categories of information include:

- basic company information (name, established year, award winning year, sector)
- description of the company
- problems faced with the company (if known)
- process of addressing the problem
- input from the company
- product/service innovation achieved
- process innovation achieved
- organisational innovation achieved
- financial/business benefits
- comment from the researcher.

3.3.4.3 Data analysis

The explicit data collection yielded systematic categorisation of the data from various sources. In order to comprehend the data meaningfully and within the confines of the context of the study (i.e. design innovation spectrum and generalised innovative manufacturing problems), an ethnographic content analysis was used (Altheide, 1987). It is a highly interactive way of analysing data from various sources including news articles, book, magazines, newspapers, and searching for context, underlying meanings, patterns, and processes (Altheide, 1996).

Table 3.6: Ethnographic contents analysis of the cases

Name	Problem	Input	Process	P/S*	Proc.*	Org.*	Benefit	Comment
Gipple (Design Council example)	Further growth and effective design an NPD.	Top management commitment Dedicated special project manager £40k investment to upgrade Ideas and Innovation Centre	Workshop (with DA) Identification of key issues and projects to add value to business Streamlining opportunity Visit Innocent Drinks (benchmarking) to create stimulating work environment	n/a	Streamlined NPD process Identification of viable idea early in development Strengthened focus in NPD	Dragon's Den-inspired idea competition (internal)- Grinnovate Framework to bring people (employees) together Innovation team (10 people)	Increase growth (10%/yr) 25% turnover every year from products less than 4yrs old	The company is now an employee owned company (GLIDE-Growth Led Innovation Driven Employee Company Ltd) which encourages ownership, dedication, open involvement to growth
Specialist Precast Products (DME Award example)	Market opportunity identified through designer collaboration	CEO dedication New division-design hub. Collaboration with external design student. New budget for branding, website, and communications materials for Edward Martyn Concrete Design EMCD	From- specification received, manufacture, delivery to- project expectations discussed, designs developed & prototyped, manufacturer & quality control- deliver & review	New range of concrete products Bespoke products from 'archinecro'	Dedicated workshop space within factory for EMCD)	New business model based on designer collaboration (new market position) New dedicated division that uses same technology and expertise but target high-valued customers	Attracting and increased high-value product customer 25% turnover in year one (increased by EMCD) expects the turnover to exceed SPP project	SPP has strong intension to filer down the creative culture of Edward Martyn Concrete Designs to the rest of SPP.
Aspen Pumps Ltd (Queen's award example)	Designing & producing products focusing reliability, performance and ease of installation	The application of in-house engineering knowledge and experience in to product development	In-house knowledge, specific market needs identification, customer feedback oriented product development, and localised training (for the engineers)	Mini Pump range that offers solutions that are designed to be simple to install and	The production facilities run using lean manufacturing principles and with focus on repeatability	n/a	Not directly, but involved in securing £105 million investment from 3i	Identified the need of easy to install pumps for condensation removal pumps for air-conditioners

Note: company information, references and some details are omitted from the original table
*** P/S = Product/service innovation, Proc. = Process innovation, Org. = Organisational innovation**

In this study, additional sources such as a case study of the winner from the awarding body, interviews or talks, and company websites provided further data. With the categories derived from the previous section, the data were analysed (see Appendix C) and some examples are shown in Table 3.6.

From the analysis each case was categorised in the areas of the spectrum created earlier in the research process. In the examples of the cases in Table 3.6, Gripple can be categorised as showing the presence of ‘design strategy for process innovation’, as they have solved the problem by streamlining and strengthening focus in NPD process, and ‘corporate-level design thinking for organisational innovation’ as they have introduced a new creative reward scheme to promote employee involvement in innovation, and structuring the company to create an environment which promotes collaboration. The challenge set forth by the Design Associate from The Design Council is met by a combination of using the two areas of the design innovation spectrum. The purpose of the case study is how it relates to the design innovation spectrum in real-life companies where it can enrich the understanding of each area. It has also created additional characteristics of each of the areas used to describe the spectrum in more depth. Furthermore, the case study has created a pattern of general problems for innovative manufacturing companies. These are used to create a set of scenarios for the implementation of the design innovation framework with the recommendation (Chapter 7) to provide cases which the innovative manufacturing companies can closely relate to, in order to implement the framework more effectively.

3.3.5 In-depth interviews

The research aims to provide a comprehensive overview of design innovation in UK innovative manufacturing companies, in the form of the design innovation framework, exploring the actions and effects of design innovation on businesses in further improving innovativeness, moving towards the Total design innovation. To achieve this it is necessary to identify design innovation characteristics for innovative manufacturing. The research context is very complex, requiring an in-depth study of the topic and its surrounding context. The interview is thus a powerful and appropriate method of information gathering, and a way to convert the implicit knowledge of the people being studied into an explicit expression of their understanding of phenomena (Arksey and Knight, 1999). A semi-structured interview approach is used to ensure flexibility when conducting the interview, whilst obtaining an in-depth understanding of the interviewee's perception and understanding of the phenomenon (Berg and Lune, 2012). In addition, the expert (also known as, elite) interview principles are adopted whilst purposively selecting the samples because the depth of knowledge and experiences are imperative in constructing a valid design innovation framework. The broad strengths and weaknesses of the interview are shown in Table 3.5 (Section 3.3.4.2). Berg and Lune (2012) list three types of interview: standardized, semi-standardized and unstandardized, depending on its formality (Table 3.7) - also known as structured, semi-structured and unstructured (Yates, 2004, Bryman, 2008).

Table 3.7: Interview structure continuum of formality

Standardized Interviews	Semistandardized Interviews	Unstandardized Interviews
• Most formally structured • No deviation from question order • Wording of each question asked exactly as written • No adjusting of level of language • No clarification or answering of questions about the interview • No additional questions may be added • Similar in format to a pencil-and-paper survey.	• More or less structured • Questions may be reordered during the interview • Wording of questions flexible. • Level of language may be adjusted • Interviewer may answer questions and make clarifications • Interviewer may add or delete probes to interview between subsequent subjects.	• Completely unstructured • No set order to any questions • No set wording to any questions • Level of language may be adjusted • Interviewer may answer questions and make clarifications • Interviewer may add or delete questions between interviews.

Source: (Berg and Lune, 2012:109)

Bryman (2008) notes that the formality of the structured interview is ideal for quantitative research where the comparison between the responses are easy to identify and quantify. Conversely, the unstructured interview – usually used in qualitative research - can provide detailed in-depth insights into the issue or topic. The semi-structured interview lies in the middle, with greater flexibility where the interviewer prepares an interview guide containing topics to be explored but not necessarily following the order, and using a mix of closed and open question techniques (see Section 3.3.3.2.)

An "expert" here is an interviewee with special knowledge of a social phenomenon, who holds an expert role in the social setting under investigation (Gläser and Laudel, 2009). It is also closely linked to the 'elite' interview, characterised by Dexter as (Dexter, 1970):

- The interviewee is known to have participated in a certain situation
- the researcher reviews necessary information to arrive at a provisional analysis
- the interview guide is based on this analysis
- the result of the interview is the interviewee's definition of the situation.

These characteristics are closely linked with the focused interview, another type of interview described by Gray (2009), which relies heavily on a particular situation and prior knowledge of that situation by the interviewer to explore the interviewee's subjective knowledge or experiences of that situation. Although the interviews broadly follow the semi-structured format, the situational awareness of any design innovation-related successes publicised by the company or other media can be a powerful catalyst in elaborating design innovation actions and their effects (Weiss, 1994). Since careful preparation is vital when conducting an expert (elite) interview (Mikecz, 2012), the particular situation is studied beforehand, in conjunction with the background of the interviewee and the company profile. The expert interviews are conducted face-to-face, to build rapport and observe the interviewee's nuances, and to gain deeper understanding (Yates, 2004, Bryman, 2008) and clarify any misinterpretation of the questions (Berg and Lune, 2012). Each interview was conducted in an environment familiar to the interviewee, to provide a comfortable setting for the respondent, and lasted between 45 to 120 minutes. The variation in interview times meant the shorter interviews had to be rigorously managed to cover all the key topics, whereas the longer interviews provided greater freedom for the interviewee to discuss in greater depth the topics they are passionate about. To allow better engagement with the interviewee, note-taking was kept to minimum, and an audio-recording was made, which eliminates limitation of memory and enables a more thorough analysis of the interviews (Bryman, 2008).

All expert interviews consist of parts which are used to evaluate certain concepts created by this research: (i) the utilisation and role of design in innovative manufacturing companies with manufacturing experts, (ii) the design innovation spectrum's comprehensiveness and feasibility with design innovation experts, and (iii) the comprehensiveness, acceptability and potential usefulness of the design innovation framework and it implementation process with both manufacturing and design experts.

Evaluation of the research included careful data collection and rigorous analysis through systematic and empirical examination of its effectiveness (Patton, 1990). As the research is qualitative in nature, it is not possible to statistically validate the research outcome, so a qualitative evaluation is used throughout the research process to enhance the validity of the theories generated by the research (i.e. design innovation spectrum, and design innovation characteristics and subsequent framework and process of implementation). The effectiveness of the concept in the context of its desired surroundings (i.e. manufacturing companies and design innovation consultancies) was not possible because of research time constraints, making expert evaluation vital to ensure that the validity of the theory is acceptable in the context which the research proposes.

3.3.5.1 Manufacturing expert interviews

The manufacturing experts comprised two distinct groups (denotation of ‘ME’ will be used to describe manufacturing experts throughout): the group of top-level managers (n=6) and the Senior or Middle managers (n=5). The two distinct groups provide diverse perspectives of the topics, as explained earlier, because the level of understanding of the company dynamic differs according to their position in the company. Furthermore, as triangulation of data, to increase reliability of the findings. The top-level managers were selected to obtain the perspectives of people who create vision for the company and make strategic decisions to realise that vision, to explore in the interview their overview of the company’s perception of design and innovation. The senior/middle managers were selected from areas of management, marketing and sales, employees who are closely related to the customers and can provide lateral understanding of the customers and the company’s products and production processes. A design group was deliberately omitted from this set of interviews as the design professionals’ opinions were studied separately later in the research.

The in-depth interviews with manufacturing industry experts had two parts. The first part was a discussion of current utilisation of design in innovative manufacturing companies, which forms triangulation of method for exploratory phase. In the second part, the role of design and innovation in innovative manufacturing companies was discussed in greater depth, in order to construct a comprehensive array of design innovation actions and their effects in innovative manufacturing companies. The outcome of the second part is then used to construct the design innovation characteristics and subsequent design innovation framework (beta-version), to be evaluated at a later stage of the research. Although these parts are divided to provide the researcher with a focus of the objectives, some of the topics are interrelated, so some responses were used interchangeably. The interview topics included:

- General information about the company (main market, current competitive strength)
- The meaning and value to the UK and to the company of innovative manufacturing
- Innovative activities within the company
- The function of design for the company
- Examples of 'good' design which increased company performance
- The consideration of design as a strategic tool for business
- Design innovation characteristics: its actions and effects in innovative manufacturing companies.

Additional questions were asked, drawing on the research conducted before the interview, about any situation where the researcher might draw out further opinions, particularly on the interviewee's perception of design. It was anticipated that the view of design is limited even in innovative manufacturing companies, but the researcher took care not to compromise objectivity and not to persuade the interviewee to give an answer. Appendix D shows the interview questions where the interviews opened with an "ice-breaker" explaining the research, using the 'contextual model of innovative manufacturing' produced as a result of the exploratory interviews and subsequent peer evaluation.

3.3.5.2 Design innovation expert interviews

The design innovation expert interview format closely followed that of the manufacturing expert interviews (denotation of 'DE' will be used to describe design innovation experts throughout this thesis). However, for design innovation experts the first part evaluated the initial design innovation spectrum created through the literature review for its comprehensiveness and acceptability to design professionals. They were asked to comment on any improvements which could contribute to create a final version of the design innovation spectrum which would provide a more acceptable overview of design innovation in the business context. A graphic representation of the design innovation spectrum was prepared for this part of the interview. In the second part, as with to the manufacturing experts, the interviewees were asked to elaborate on design innovation actions and effects in the innovative manufacturing context, with examples of successful executions. Appendix E shows the interview questions. The main topics explored were:

- An interviewee-specific ice-breaker about their work: consulting or being involved in interesting projects
- The design innovation spectrum:
    - comprehensiveness to promoting the value of all areas of design to innovative manufacturing companies
    - feasibility of including design thinking (corporate-level)
    - increasing design capabilities in designing, design strategy and corporate-level design thinking
    - areas of design improvement for innovative manufacturing companies
- The relationship between design and innovation
- Influences of design for innovation in innovative manufacturing companies
- Design innovation characteristics: its actions and effects in innovative manufacturing companies.

The design innovation experts were divided into three groups. The first group comprised the design professionals (n=5): design innovation consultants with experience of helping UK innovative manufacturing companies improve their innovativeness through design in extensive areas of design innovation, as specified in the design innovation spectrum. The second group comprised experts from a design support NGO (n=3), whose focus is promoting the value of design, running programmes (partly government funded) which support UK manufacturing companies to utilise design more comprehensively. The third and final group comprised interviewees from a government body (n=3) responsible for supporting innovation in the UK mainly for manufacturing companies, helping them successfully commercialise collaborative R&D efforts, usually between universities and companies. The three groups were chosen to represent the design innovation experts, because the literature review and exploratory interviews revealed that these are the areas most likely to influence the development/improvement of design innovation in innovative manufacturing companies.

3.3.5.3 Evaluation interviews

A test (beta) version was developed of the design innovation framework and its prospective implementation process, by identifying the design innovation characteristics derived from the interviews with manufacturing and design innovation experts. The evaluation by the expert interviews was effectively a qualitative enquiry, intended to identify the effectiveness of the phenomenon under study (Patton, 1990). The experts in this study comprised potential users in innovative manufacturing companies and in design innovation consultancies who were able to provide a practical assessment of the framework (denotation of 'EE' will be used to describe evaluation experts throughout this thesis). The interview questions are provided in the Appendix F. The evaluation experts comprised top-level managers (n=4), design managers (senior or middle managers) of innovative manufacturing companies (n=3), and top-level managers of design innovation consultancies (n=3). Among the evaluation experts, two design innovation experts were invited back, asked the same questions as other evaluation experts, with an additional question about whether their views were correctly captured in the framework. The two experts were chosen because they were among the interviewees who articulated their thoughts more effectively, providing opinions which proved essential to building the framework.

The thirteen-page design innovation framework booklet (see Appendix G) covers the details and implementation scenarios of the framework; a further twelve pages of supporting details, much like an appendix, was prepared before the interview. The electronic version (pdf) of the booklet was sent to the interviewees prior to the interview to save time during the interview. The printed version of the framework booklet was used during the interview, going through the booklet and allowing the interviewees to think aloud, while asking questions about:

- The acceptability and potential usefulness of the framework (overview) and its elements and relationships between the elements
- The comprehensiveness of the design innovation characteristics
- Feasibility and ease of understanding of design innovation characteristic influences on the benefits of design innovation
- The usability of the generic design innovation implementation process

- The acceptability of the scenarios presented
- The potential usefulness of the process and framework overall
- The overall presentation and suggestions for improvements.

3.3.5.4 Sampling

In qualitative research, non-probability sampling is the most popular way of selecting the sample because it focuses less on the population representation, more on a deeper understanding of cases, events, or actions (Neuman, 2003). The different types of non-probability sampling depend on how they are selected. Berg and Lune (2012) list three major types: convenience, purposive, and snowball sampling. Convenience sampling is when selection of samples occurs by chance, a type of sampling which is seldom appropriate for qualitative research. It is relatively less time-consuming compared to other types of sampling, but often requires careful data interpretation, as it can be irrelevant to the objectives of the study (Bryman, 2008). Purposive sampling is often used in exploratory research where the researcher uses his or her judgement to select the most appropriate samples providing insight in the research context (Neuman, 2003). Snowball sampling uses small initial samples to find other people with similar attributes. It is similar to convenience sampling in that it collects data based on chance, so it also requires careful analysis to collect satisfactory data which provides in-depth explanation of a phenomenon.

Purposive sampling was used for the expert interviews in order to explore the research question in depth (Bryman, 2008, Matthews and Ross, 2010, Silverman, 2010). It is a particularly appropriate sampling method for an expert interview because the experts are selected with criteria set by the researcher to provide in-depth knowledge (Gläser and Laudel, 2009). The initial list of potential interviewees was generated using various methods (Neuman, 2003) including design and manufacturing conferences/tradeshows, researcher’s academic and professional networks, and websites of relevant organisations, e.g. The Design Council, and several design and innovation awards (including the DME Awards and the Queen’s Awards etc.,). Lists of potential interviewees were then generated and further studied to select those most appropriate for the research objectives. In order to minimise researcher bias (Silverman, 2010), the interviewee selection was reviewed by academics and peer researchers from design management and manufacturing/engineering.

The manufacturing experts were required to demonstrate certain attributes which would provide the in-depth knowledge this research requires. So as part of the purposive sampling process, the interviewee criteria of manufacturing experts were created using literature reviews and exploratory interviews. The experts should:

- Manage or work for an innovative manufacturing company in the UK (see criteria for innovative manufacturing in Section 2.5.4) with at least ten years' experience in the industry
- Understand the overall operations of the company's business and be interested in manufacturing development in the UK
- Have an active interest in personal and/or organisational improvements in order to gain competitiveness
- Be involved in developing new or improved products/services/processes and/or organisational changes in order to improve the company's innovativeness.

A list of possible interviewees was screened, using the interviewee criteria. The selected interviewees are shown in the Table 3.8 with a brief interviewee profile and their expertise.

Table 3.8: Manufacturing expert profile

Interviewee	Title	Organisation (manufacturing sector)	Profile/Expertise	Experi-ence in industry
ME1	Managing Director	Computer Aided Design and Manufacture	Extensive experience in business and corporate strategy in engineering software marketing, optimisation of manufacturing system and processes.	27 years
ME2	Managing Director	Anti-ligature locks	Entrepreneurial mindset with experience in manufacturing products for health and the medical sector.	20 years
ME3	Managing Director	Theatrical and stage equipment	Strategy for product and process innovation which made the company a primary source of products in its sector.	26 years
ME4	Managing Director	Small-batch product manufacturing	Holistic approach of engineering design in the manufacturing process in on-demand based consulting and manufacturing.	10 years
ME5	Partner	Filters for oil and energy	New technology adaptation to extend the product range and optimise the process. Bespoke filters with a heavy emphasis on quality.	29 years
ME6	Director	Prototype and small-batch products	Rapid prototyping using various technologies for fast turnaround, high quality and customer satisfaction. Extensive experience in customer service.	22 years

ME7	Technical Manager	Tube fabrication for the automotive, aviation and marine industry	Involvement with engineering and design departments to understand the holistic overview of the strength of the company and its products.	15 years
ME8	Division Manager	Aero and automotive engine parts	Manufacturing process and product applications. Worked with one company for his entire career- insight into company operations from an employee perspective.	21 years
ME9	European Marketing Manager	Milling, turning, 5-axis, CNC machines	Extensive dealings with manufacturing companies. Communication both with customer and project partners/ suppliers.	19 years
ME10	Commercial Metrology Manager	Digital readout systems	Mechanical engineering background with PgDip. in business administration providing technical understanding that transfers to identifying new business opportunities.	15 years
ME11	General Manager	Plastic injection moulding products	Exploring new market opportunities and product servicing. Frequent interaction with customers to understand their requirements.	10 years

Note: the top-level manger group comprises ME1 to ME6, and senior/middle manager group comprises ME7 to ME11

As with the manufacturing experts, the design innovation experts were selected using criteria developed through the literature review, including:

- Managing or working for more than ten years for a consultancy or organisation which provides service to help further improve innovativeness through design for innovative manufacturing companies
- Experience of working or collaborating with top-level managers of innovative manufacturing companies
- A comprehensive view of the value of design, both in the activity and in the advancement of business as whole (corporate-level design thinking)
- Understanding the relationship between design and innovation.

The criteria can occasionally be difficult to gauge without any pre-selection engagement, so unless the potential interviewees are known to satisfy the criteria through professional engagement by the researcher, the supervisor, or internet information, unstructured pre-selection interviews were conducted to determine the interviewee's suitability. The final interviewees selected are listed in Table 3.9.

Table 3.9: Design innovation expert profile

Interviewee	Title	Organisation	Profile/Expertise	Experi-ence in industry
DE1	Creative Director	Design Innovation Consultancy	Extensive experience of leading multi-disciplinary teams with projects for clients ranging from multinationals to small technology start-ups, helping them apply a human-centred approach to identify and solve product and business problems with a multitude of outcomes, including concept generation, prototype, product/service design, opportunity finding, better NPD process, creating innovation cultures, etc., affecting all levels of businesses.	15 years
DE2	Director		Founding partner of an industrial design and product development consultancy which has won numerous awards over the years, demonstrating the effective application of design in commercial success. Also a director of a leading UK design association, and extensive experience of lecturing in various universities on design in business.	34 years
DE3	Principal		Specialising in innovation strategy and management with a background as a product designer and management consultant at a global firm. Currently a design strategist and innovation advisor with experience in cultivating innovation for multinationals and SMEs and NGOs. Original developer of a globally-used design toolkit for increasing innovativeness in business through design.	29 years
DE4	Director		Trained as a furniture designer but with extensive experience in the creative and commercial application of design innovation in brand, product and service development with B2B and B2C companies. Strong advocate of the value of design in making the client succeed in the market.	35 years
DE5	Associate Director		Cultivating ideas into feasible products focused on commercial success for both clients and users. Experience in holistic application of design thinking in all levels of business, and in creating spinout companies from in-house projects.	22 years
DE6	Design Advisor	Design Promotion and Support NGO	Business advice, working with UK businesses to provide client-focused creative business advice and coaching. Also provides design advice on brand identity, product design, user-centred design IP rights, market and communication strategies.	32 years

DE7	Head of Design, Leadership		Experienced in managing the pool of design advisors in the NGO, through which he has critical insight on how design is perceived and how to convince companies of the value of design when used in all levels of business.	15 years
DE8	Design Advisor/ Design Innovation Consultant		Product design background with an interest in human-centred design techniques to help businesses innovate through applying practical and effective design strategy and design thinking to ensure business growth. Original developer of the design framework used by design advisors in the NGO.	30 years
DE9	Lead Technologist	Governmental Innovation Support Organisation	Specialises in helping high-value manufacturing researches become commercialised with his extensive experience in product development and component design in the automotive and aerospace industry. Interested in broader perceptions of design.	35 years
DE10	Head of Development Innovation		Design advocate in a technology- and research-focused organisation where he initiated a programme for the use of design as a tool to enhance commercial success for UK innovative manufacturing companies.	11 years
DE11	Design Mentor/ Director		Design director for a design consultancy with twenty years' experience. Then became MD and Creative director for an innovative manufacturing company specialising in technically advanced audio products.	34 years

As mentioned in the previous section, the evaluation experts comprised prospective users of the design innovation framework and its process of implementation. They are experienced in the practical delivery of innovation improvement in one or more areas of design innovation in the design innovation spectrum (Table 3.10). The criteria for these interviewees were:

- Has managed or worked for a company/consultancy with experience of improving the innovativeness of the company
- For manufacturing companies, it must be within the criteria of innovative manufacturing Section 2.5.4
- Understands the overall operations of the manufacturing business and has an interest in process or management improvements
- Identifies the impact (value) of design and/or innovation in all levels of businesses.

Two of the most active design innovation experts (interviewees DE3 and DE11) in the earlier interview were re-selected to be involved in the evaluation process, and were asked for their opinion whether the framework encapsulate the interview conducted previously to identify any errors in data analysis.

Table 3.10: Evaluation expert profile

Interviewee	Title	Organisation (manufacturing sector)	Profile/Expertise	Experience in industry
EE1	Director	Manufacture of plastic products	PhD in Chemistry, now managing the family business. Particular interest in process and organisational innovation and has developed the company to become a world leader in its sector.	17 years
EE2	Vice President of European Manufacturing	Medical devices	Responsible for all the manufacturing sites in Europe of a global manufacturing company. Engineering background with extensive experience in manufacturing process inc. Lean, Six sigma and TQM.	39 years
EE3	MD	Lighting	PhD in electric lighting systems, with an architecture and engineering background. Particular focus on quality reliability and flexibility in manufacturing lightings for B2B and B2C customers	20 years
EE4	Director	Electrical equipment	Same as DE11.	34 years
EE5	Engineering operations leader-innovation	Material handling	Head of the innovative product development unit of a global manufacturing company. Extensive experience in dealing with multiple demands from different departments and successful internal and external collaborations to create efficient solutions for customers.	35 years
EE6	Engineering & Design Business unit manager	Aerospace	Mechanical engineering background with extensive experience in design engineering and an interest in process innovation for manufacturing systems, applying design thinking holistically to lead in several special projects.	15 years
EE7	Design and development manager	Manufacturing fabrication	Special interest in knowledge management for manufacturing systems. A PhD in environmental science with a mechanical & design engineering background. Responsible for managing a team of designers (engineers) developing new products with direct engagement with customers and top-level managements.	11 years

EE8	Design director	Strategic design innovation	Expert in design management converting ideas into profitable propositions by using design holistically in all levels of a company, from NPD to strategic management of a manufacturing company. Extensive experience in advising companies through both NGO and governmental industry support schemes.	28 years
EE9	Partner	Business consultancy (design innovation)	Interior design background, with extensive experience of advising companies to enhance innovativeness through holistic design thinking. Business mentor for start-up businesses in government funded scheme and NGOs.	40 years
EE10	Principle	Design innovation consultancy	Same as DE3.	29 years

3.3.5.5 Data analysis

The in-depth expert interviews produced rich raw data with recordings of over thirty-six hours of audio conversations, which were transcribed and analysed to provide meaningful data, to fulfil the research objectives. A system of coding methods was used: ‘open coding’ was followed by ‘axial coding’, and finally ‘selective coding’, to identify the design innovation action, effect and benefits which form the design innovation characteristics, and eventually the design innovation framework. For the final evaluation interviews, content analysis was used to validate the concept and identify final improvements to be made.

Qualitative analysis is a process of systematic interpretation of data gathered from the qualitative research in order to identify meaningful patterns, themes and concepts (Henry, 1990, Yates, 2004, Gray, 2009, Silverman, 2010, Berg and Lune, 2012). It is generally more prone to researcher subjectivity (Gray, 2009), and lacks well-established and widely accepted rules (Bryman, 2008, Berg and Lune, 2012, Saldaña, 2013) compared with quantitative analysis. However, qualitative data analysis can create concepts and theories from complex phenomena such as that in this research, without being confined by the laws of statistics (Neuman, 2003). To address the issue of qualitative analysis, and produce sound theory from the data, a systematic approach of interpreting data, coding, was used for this research. The approach suggested by Neuman (2003) and Corbin and Strauss (2008), which consists of open coding, axial coding and selective coding, was used to analyse the expert interviews. Coding was done manually, as suggested by Saldaña (2013), because the researcher also felt it provided more control and increased ownership of the work. As explained earlier, the interviews with design and manufacturing experts had two parts: evaluation, and design innovation in innovative manufacturing. However, it was apparent in most cases during evaluation that the interviewee described many aspects which can be used to understand design innovation in innovative manufacturing. In the coding process the two parts were combined unless the comment was specific to evaluating subjects (i.e. the design innovation spectrum) which are noted separately.

Firstly, open coding was used to capture an idea, process or theme from the interview transcripts (Neuman, 2003). It is also called eclectic coding (Saldaña, 2013), encapsulating the data without too much researcher intervention or interpretation. The initial codes (preliminary codes) were analysed again to create the final codes and the researcher's note, taken either during interview or while coding, is added to provide some context to the codes (Table 3.11). The axial coding followed the open coding to identify the relationship between the codes, paying particular attention to the causes and consequences where the initial categories are generated (Neuman, 2003). Both preliminary and final codes were considered during the axial coding process with great attention to capture ideas, causes and consequences where causes are regarded as the action of design innovation and consequences are the effect the actions have on innovative manufacturing companies. Some comments were negative e.g. from Table 3.11, cause: "not considering people", consequences: "falling revenue." Within the boundaries of not changing the meaning, these were converted to a positive statement, i.e. cause: "consider people", consequences: "increased revenue." Thirty-five major themes (design innovation characteristics) were identified by the axial coding process (Figure 3.3). The final stage of the coding process used selective coding to clarify certain relationships and create an overall analysis by scanning data and previous codes (Neuman, 2003) to form the grounded theory (Gray, 2009). At this point, the characteristics were reviewed and reduced to twenty, and the major concepts were generated: the six benefits of design innovation. Stories were created to encapsulate the major themes identified (Corbin and Strauss, 2008) and used to describe each characteristic. The literatures were then used to further explain the relationships identified during the selective coding process which reinforces the theory (Chapter 6).

Table 3.11: An example of open coding

Original Comments of DE1 from 9:00 to 10.45	Preliminary Coding	Final Codes	Researcher's note
...anything we do to develop products and services in companies is about the person, and often key people are missed out and that's why products or services don't either generate enough revenue for a company or aren't as appreciated by consumers. So out take is to brand it human centred design in every level. And a lot people see human centred designer, kind of research, and insight that you have to do research with humans and it's not, it's about understanding company and who the stakeholders are, and they are all human, so how do you map out and make sure that you are bringing the right people together. How do you make sure that the production line who are making your products know why certain elements are critical to the execution of a product because you brought them on board a journey so it's about engaging with people. And it does come back to research, in terms of user research of how is the product, how could you look at space where there is a need or how people are doing things wrong. So going back to your question of design thinking, yes it does. I think it's just another. I don't know in terms of how people like the IDEO have approach it if they are selling it as a tool. But I think it does encompass everything from understanding why you are doing something to how it is then executed internally and externally. How you get your whole team onboard that this is because if you have buy in internally that's probably more than 50% because if they are all passionate about doing something then they are going to make sure that the execution is perfect to the market.	Product/service are about person Not considering people Falling revenue Company not appreciated Human-centred design in every level Perception of Human-centred design is research with humans Understand company and the stakeholder Mapping the stakeholder Bringing people (stakeholders) together Communicating the purpose of design with other departments Engaging, collaborating with internal/external people Looking for market niche/need User opportunity/need Design thinking covers everything Reason for action Internal and external process Internal collaboration Internal buy-in Staff engagement Staff ownership Quality improvement	**User understanding** **People-centred at all levels** **Understanding stakeholders** **Internal/external Collaboration** **Communication** **Market demand/ need** **User demand/ needs** **Reason (value) promotion** **Staff ownership/ engagement** **Quality**	Human-centred design is the main motto of the consultancy, therefore it can be replaced by 'design' in broad term Attributes of design communicated to internal staff as well as the customers Design used to look for market demand/need through human-centred research Design thinking described here as philosophy of design principles

Design Innovation Spectrum		Design Innovation Qualities or Charateristics	Description
Designing (Product/Production/Communication/Service)	Technological Innovation	Product Functionality	the products/services have appropriate functions which are desirable to the customers.
		Reliability	the products/services are known for their reliability which exceeds user expectation.
		Detail design for manufacturing	the design of products include details which are optimised for production/assembly.
		Problem identification	the company regularly searches for problems with both their own and their competitors' products/services.
	Product, Service, Process Innovation	User research (needs)	user research is integral to understanding the needs of both existing and potential new users.
		Branding (external)	the company and products / services have high brand presence in their sector and the market.
		Visual communication	the company engages external communications with clear easy-to-understand materials.
		Customisation (Flexibility)	the company has flexibility to enable customisation of its products/services.
		Aesthetics	the products have perceived high quality aesthetics which are distinctive in the market.
		Usability	the products/services are easy and intuitive to operate with a clear interface.
		Fit for user needs	the products/services fully meet the users' needs (specifications) without regular after-launch adjustments.
		Fit for market demand	the products/services have a distinctive presence in a growing market.
Design Strategy (Managing Design)		Customer engagement in NPD	the company actively seeks and uses customer feedback in the NPD process.
		Short lead time	the company has a shorter lead time for its products/services than the competition.
		Feasibility testing (prototyping)	the company carries out early feasibility testing to minimise production and market failure.
		Automation	a high level of automation is practised in production / quality management processes.
		Consistent quality (QM)	quality management is practised to produce consistent quality products / services.
		Process optimisation (lean)	regular evaluations are conducted to optimise process to reduce wasting resources (time/material).
		Market opportunity identification	the company regularly and successfully identifies new market opportunities.
		Teamwork	the employees across the company have a sense of being in one team.
		Sales channel evaluation	the company has established and reliable sales channels with good exposure to the users.
	Organisational Innovation	Performance evaluation	financial and technical performances are regularly analysed for further optimisation.
		Regular product launch	the company regularly launches new/radically improved products/services.
		Cross-department collaboration	all departments are involved throughout the NPD process with regular open discussions.
		External collaboration	the company collaborates actively with external experts and companies to create synergy.
Corporate-level Design Thinking (Managing Company)		Encouraging idea generation	the company has a culture of ideas-generation and sharing across all levels of business.
		Knowledge capture (KM)	the company has a system of managing knowledge gained from experience (tacit knowledge).
		Top-level management support	the top-level management champions the importance of design innovation.
		Investment (people, tool, R&D)	the company regularly invests in people, machinery and R&D to increase innovativeness.
		Open company culture	the company is less hierarchical and more flat structured, acknowledging employees' strengths.
		Relationships with clients (trust)	the company has engagement across manufacturing value chain and trusting relationships with suppliers/clients.
		Risk evaluation	risks are identified, monitored, and regularly reviewed.
		Business model creation/testing	clear business model with regular evaluation to compensate the rapidly changing market.
		Internal communication (vision)	the company has clear vision and strategy which is communicated effectively across the company.
		Work environment	the company has a physical work environment which encourages employees to collaborate and share ideas.

Figure 3.3: Initial design innovation characteristics identified after axial coding process

The evaluation of the design innovation framework was analysed using the technique of content analysis because it can be used to test the theory (Gray, 2009, Berg and Lune, 2012) and because the aim of the evaluation was not to create a new theory but to analyse the theory already created (i.e. the design innovation framework) and to improve the initial framework so that the final framework can be created. Berg and Lune (2012) explain that in order to analyse data objectively the “criteria of selection” must be established prior to analysing the data. The key discussion topics were thus adopted as the selection criteria for the content analysis process, which includes feasibility, acceptability, usability and improvements. The data then were used as a guide to make final improvements and to concept-prove the theory generated from the research.

3.3.6 Reliability and validity

This research considered the reliability and validity throughout the research. To increase reliability, methods and data triangulation were employed, and to increase internal validity rigorous self-assessment and evaluations were used throughout the research, from the academic reviews and conference presentations. External validity was paramount for the research, because the research seeks to provide recommendation for practical application for innovative manufacturing companies. Therefore, evaluation research was conducted by testing the theory for its practical implications as a major part of the research.

Triangulation of methods and data was used in the exploratory phase of the research where it used a questionnaire survey and in-depth interviews to understand the perception and the role of design in innovative manufacturing companies. As already mentioned in Section 3.3.3.1, methods triangulation also provides increased validity (external) by addressing the limitations of the questionnaire survey. In order to increase validity in the exploratory phase of the research, a series of meetings took place with academics in design and manufacturing from Brunel University London and Lancaster University. Before distribution, the questionnaire survey was evaluated and revised several times, with the academics and the in-depth interview topics were revised to ensure necessary information could be collected. The meetings also provided an opportunity to increase the validity of the analysed data and subsequent models (the contextual model of innovative manufacturing). Presenting the research at the international design management conference, the DMI Design Management Research Conference ‘Leading Innovation Through Design’ (Boston, August 2012), also increased the validity of the research.

In the development phase, methods triangulation was achieved by using in-depth interviews and case studies to construct the design innovation spectrum to increase the reliability of the data. At this stage, evaluation of the design innovation spectrum (i.e. in-depth interviews) was used both as part of triangulation and also to enhance the external validity of the theory created for this study. In the development phase to identify the design innovation characteristics, data triangulation was used within the twenty-two in-depth expert interviews. This was achieved by purposively sampling the experts in two groups - manufacturing experts and design innovation experts - to elicit rich data which can provide a reliable construction of the theory. The internal validity has been increased through discussion with academics and industrialists on the discussion topics of the in-depth interviews. Furthermore, the selection of the expert interviewees was particularly important to increase the validity. Therefore rigorous sampling tests through discussions with the academics in design and manufacturing, on-line sources and unstructured interviews with potential experts were conducted.

The external validity of the research was increased by a dedicated evaluation research study at the evaluation phase, where ten prospective design innovation framework users were interviewed to provide opinions on its acceptability, feasibility and usability. Prior to the interview, several iterations of the interview topics and the material (design innovation framework booklet- Appendix G) were conducted to further increase the validity. Two interviewees (design innovation experts) who were also involved in developing the design innovation characteristics were asked about the representativeness of the theory (design innovation framework) through the data they provided, thus further increasing internal validity.

Reliability is determined by asking whether the research result can be repeated with consistency and dependability (Neuman, 2003, Bryman, 2008). The aim of reliability is to minimise errors and research bias (Yin, 2009). As the concept of reliability comes from quantitative research, some qualitative researchers argue that the same principle cannot be applied as the data sources and collection activity have an “organic” relationship with the researcher which evolves as the research progresses (Neuman, 2003). Reliability can nevertheless be improved by data triangulation, investigator triangulation, and methodological triangulation (Denzin, 1978, Dellinger and Leech, 2007, Fielding, 2012). Data triangulation is achieved by collecting data from different sources: time, spaces and persons. The purpose of data triangulation is to increase reliability by gathering data of the same phenomenon with multiple samples (Denzin, 1978). Investigator triangulation increases reliability by using two or more observers to eliminate bias towards collecting and interpreting data (Gray, 2009). Methodological triangulation uses multiple data-gathering methods for the same phenomenon (Fielding, 2012). This is also referred to as mixed methods, which is readily used by social researchers to increase the reliability of their research (Dellinger and Leech, 2007).

Validity is closely related to reliability. Reliability is concerned with data consistency, and validity is concerned with whether the data is a true representation of the phenomenon under study (Neuman, 2003). The concept of validity also comes from quantitative research. Again, as with reliability, there are arguments about whether the same principles of validity can be applied to qualitative research, especially on the criteria of validity (Guba and Lincoln, 1994, Dellinger and Leech, 2007). There are no universal definitions of validity for qualitative research and there are up to seventeen different terms for validity in qualitative research (Maxwell, 2005). This research therefore adopts both internal and external validity criteria because they are readily adapted for qualitative research (Neuman, 2003, Bryman, 2008, Gray, 2009, Yin, 2009) and comprise many of the different interpretations of the terms, e.g. credibility is the equivalent of internal validity, transformability is the equivalent of external validity, and dependability is the equivalent of reliability (Guba and Lincoln, 1994, Bryman, 2008). Internal validity is concerned with the integrity of research design and data interpretation where there are no errors (Neuman, 2003) and presents consistency in the observations and theory developed by the researcher (Bryman, 2008). External validity is predominantly about the generalisability of the research. The qualitative researcher frequently uses purposive sampling with a limited number of samples, so the question of generalisation occurs in qualitative research. The number of samples (sample size) appropriate for interviews ranges from two to twenty-five, according to different authors (Beitin, 2012) and some only provide guides to choosing samples (Bryman, 2008, Gray, 2009, Berg and Lune, 2012). As the range of appropriate sample sizes depends on the research, theoretical saturation is often used to increase research validity where the theoretical saturation occurs when the theory created by the researcher is repeated by the interviewees (Bryman, 2008).

3.3.7 Research ethics

This research closely follows Brunel University's 'Code of research ethics' (CoE, 2010). The researcher has taken the appropriate recommended ethics course (BBLearn, 2012) in order to become familiar with the ethical implications of the research and its effects on participants, the university and the researcher. In accordance with the code of ethics, appropriate measures were taken to ensure that the research participants were fully aware of the process and that they can at any time stop their participation in the research. Consent of information was agreed, and interviewees were reminded at the outset that the information provided would be kept strictly confidential and anonymised. As the research does not involve human tissue or other biological samples or deal with a group of people who are vulnerable or unable to give information and consent, it was considered low-risk and approved by the Brunel Research Ethics Committee.

3.4 Chapter summary

This chapter has explained and justified the research methodology. It provided an overview of the three main research phases: (i) exploration, (ii) development, and (iii) evaluation. The methods, including literature review, exploratory interview and questionnaire survey, case study and in-depth expert interviews, and its sequences, were selected and strategically analysed to enhance the reliability and validity of the research outcome: the design innovation framework for UK innovative manufacturing.

The next chapter presents the findings, analysis and discussion of the exploratory study, including the exploratory interview, questionnaire survey and in-depth expert interview, in the context of innovative manufacturing, and the perception, role and use of design in innovative manufacturing.

Chapter 4. Design and Innovative Manufacturing in the UK

4.1 Introduction

This chapter further explores innovative manufacturing, discussing the findings from the exploratory interviews with manufacturing academics, to identify the innovative manufacturing context in advanced, high-value manufacturing, to explain the position of innovative manufacturing for innovation and business values. The exploratory questionnaire results are analysed to better understand the market and the strength of UK innovative manufacturing companies. Further analysis and discussions then explore the perception and use of design in manufacturing companies through the exploratory questionnaire and a series of in-depth interviews with manufacturing experts. The face-to-face semi-structured interviews with manufacturing academic and experts (Table 4.1) were designed to extract maximum information without researcher bias (see Chapter 3 for method details).

Table 4.1: Brief index of interviewees

Interviewees		Organisation
Manufacturing Academics	MA1, MA2, MA3, MA4	UK University
Manufacturing	ME1, ME2, ME3, ME4, ME5, ME6, ME7, ME8, ME9, ME10, ME11	UK Manufacturing Business

This chapter presents the data-gathering and analysis of the research which formed part of a BRIEF (Brunel Research Initiative & Enterprise Fund) research, 'Design Policy for Innovative Manufacturing in the UK' (Principal Investigator: Dr Youngok Choi), which aimed to create an agenda for developing a national design policy. In this collaborative research with Lancaster University, the author contributed to planning the research, including identifying appropriate research methods and stakeholders. Collection of all data (through face-to-face interviews and questionnaire survey distribution and collection) and subsequent analysis were also conducted by the author. A series of project meetings with academics from Brunel University London and Lancaster University took place at key milestones of the project to evaluate the outcomes. In August 2012 the researcher presented the research findings at the DMI research conference 'Leading Innovation Through Design', Boston (Na and Choi, 2012). Further analysis were conducted after the conclusion of the BRIEF project to ensure that the outcome of the study is relevant to this research. This chapter therefore discusses both macro- and micro-level issues regarding innovative manufacturing and the role and usage of design in this context as shown in the chapter map (Figure 4.1).

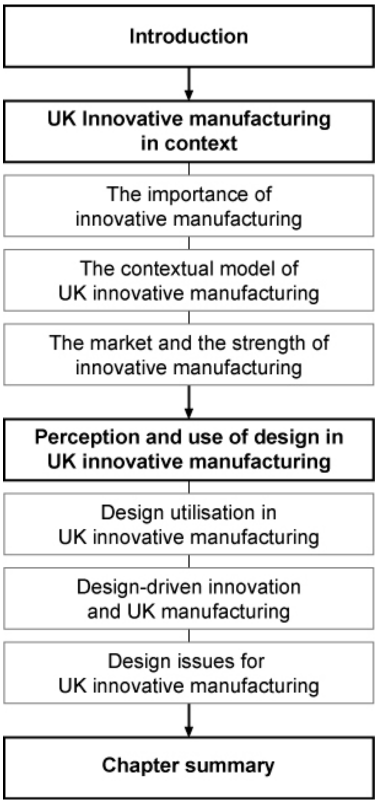


Figure 4.1: Chapter Map

Design is regarded in manufacturing as one of the most important ways to increase competitiveness (Howkins, 2002, Cox, 2005), but some believe design is under-utilised across the entire manufacturing sector (Cox, 2005, Livesey and Moultrie, 2009). When design is seen as an activity, ('Designing', as described in Chapter 2), it is clear that design is practiced in almost all manufacturing companies which produce products, whether for consumers or other businesses (DC, 2007). However, if design is viewed as an expanded practice which includes design strategy and design thinking - which is the view of this research - then design use falls dramatically, as the overwhelming majority of manufacturing companies spend on design within the activity level of businesses only (Livesey and Moultrie, 2009). The contextual model developed through the exploratory interviews with manufacturing academics, together with the literature reviews in Chapter 2, illustrate that innovative manufacturing can indeed increase different types of innovation, and subsequently expand business values. However, the exploratory survey found that the majority of innovative manufacturing companies still see design as a limited activity in the company, rather than as a strategic tool for improving innovativeness. This chapter discusses the perception, use and role of design in an innovative manufacturing context.

4.2 UK Innovative manufacturing in context

4.2.1 The importance of innovative manufacturing

The UK government regards UK innovative manufacturing as strategically important, together with advanced and high-value manufacturing (TSB, 2008, BIS, 2009, PACEC, 2011, TSB, 2011a). In this research literature reviews and exploratory interviews with manufacturing academics were undertaken, in order to understand the innovative manufacturing context, and the distinctly close interlinked relationship between advanced, high-value and innovative manufacturing. However, depending on how they are described, various governmental and non-governmental organisations have differing views. The meaning of innovative manufacturing depends largely on how ‘innovation’ is interpreted in various contexts. However, in the context of advanced and high-value manufacturing, its focus is predominantly on the process of technological innovation. The term “innovation” is often abused: one academic expert criticised it as a meaningless “buzz word” (interviewee MA2), often used by people “outside” manufacturing (interviewee MA3). The key milestones of manufacturing, according to interviewee MA3, are mass manufacturing, lean manufacturing, and high-precision, automation and sustainable manufacturing, rather than innovative manufacturing. There was also a strong preference for the term ‘high-value manufacturing’, which describes measurable outcome to produce high financial return and/or high value to customers, whether the customers are consumers (B2C), businesses (B2B) or even nations e.g. government procurement of defence and military goods (interviewees MA1, MA2 and MA4). On the contrary, advanced manufacturing is regarded as being based on currently available technology (interviewees MA1 and MA3) where it can be described as ‘advanced’ if the technology has exclusivity, which also implies that it cannot be called advanced once the novelty wears off (interviewees MA1 and MA4). However, despite reluctance to explain what innovative manufacturing is, all the experts emphasised the importance of innovation. These conflicting opinions are expected, as ‘innovation’ is open to different interpretations, and it can sometimes be challenging to define and categorise its effects in manufacturing.

The exploratory questionnaire result shows, predictably, that the overwhelming majority (92%) of innovative manufacturing companies feel that innovation is important or very important for their company, where it provides competitive advantages. The most effective area of innovative manufacturing is considered to be in creating a new opportunity in the market (65%), followed by developing new technology, increasing sales and driving down production costs, as indicated in Figure 4.2.

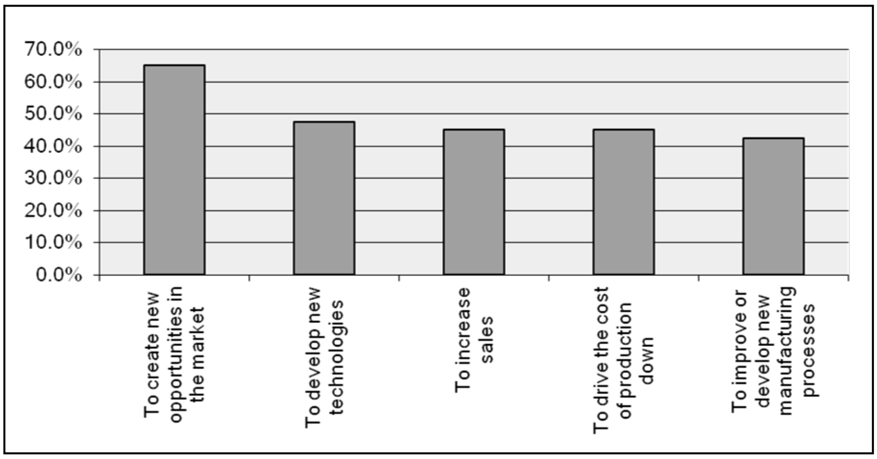


Figure 4.2: Most effective areas of innovative manufacturing (Multiple answers), (Questionnaire survey result)

A large proportion of the companies felt that innovative manufacturing is the most important factor for growth in the UK manufacturing industry (77%). Those who disagreed made some interesting comments. One manufacturer said innovative ‘design’ is the most important, commenting that “how it is made can be largely irrelevant: if the product is right the manufacturing method will follow.” Two others commented that adequate government funding/backing is the most important factor, and three others said that economic factors -

including a buoyant confident economy, reduction of labour costs, and exchange rates etc., - are the most important growth factors in UK manufacturing.

4.2.2 The contextual model of UK innovative manufacturing

On advanced and high-value manufacturing, the manufacturing academics strongly emphasised innovative manufacturing as a process to enhance and/or enable advanced manufacturing to achieve high-value manufacturing (interviewees MA1, MA2 and MA4). Innovative manufacturing is thus described as an enabler for advanced manufacturing (technological value) to expand towards high-value manufacturing (commercial value) where examples of high-value manufacturing include the aerospace, automotive, medical and energy industries (TSB, 2012c). This further encourages the growth of high-value manufacturing and subsequently of all manufacturing industry. A conceptual manufacturing model of UK manufacturing is thus developed (Figure 4.3), representing the relationship between advanced, high-value and innovative manufacturing where innovative manufacturing is described as a business or process.

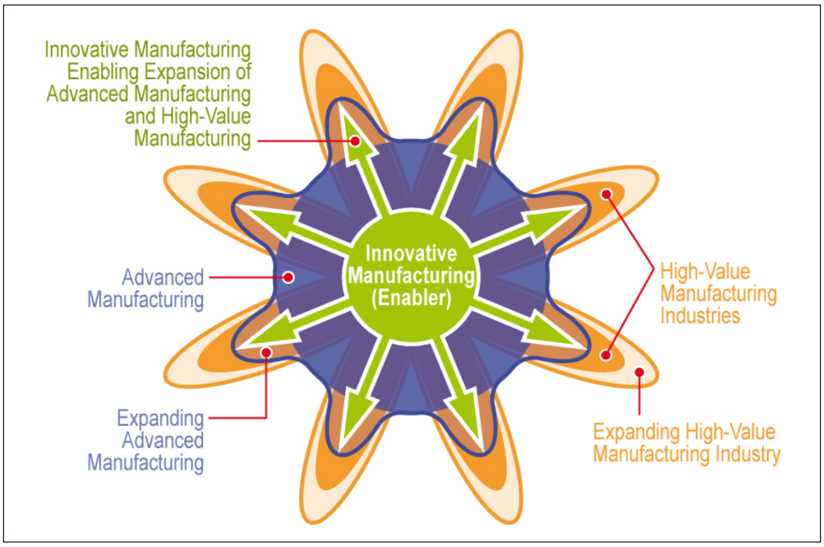


Figure 4.3: Contextual model of UK innovative manufacturing in relation to advanced and high-value manufacturing

Source: (TSB, 2008, BIS, 2009, PACEC, 2011, TSB, 2011a), (interviewees MA1, MA2 and MA3)

The definition of innovation in this context is inherently technology-based. However, the research considers innovation to have wider meaning, so it must be stressed that the role of innovative manufacturing in the UK is not limited only to enabling expansion of advanced and high-value manufacturing. The ability of innovative manufacturing to encourage the growth of advanced and high-value manufacturing is important in macro-level, as they are seen as strategically important areas to develop for the UK to sustain its position as a top manufacturing nation (BIS, 2010c). At micro-level, the benefit of innovation in products, services and organisational management greatly increases competitiveness in the wider manufacturing industry, as discussed in Section 2.5.4. The description of advanced and high-value manufacturing, drawn from the literature reviews and the interviews, can be used as a typological example. Advanced manufacturing can thus be seen as representing a type of innovation, i.e. 'technological innovation' among technological, product, process and organisational innovations (see Chapter 2), as it describes technological advancement, and high-value manufacturing can be viewed as integrated business values for companies, i.e. 'high-value in sales and turnover' in customer satisfaction, sales, turnover, operating cash flow, investment, R&D and product quality (Gomez, 1999), as it represents commercially high-value manufacturing. This is adopted to create a more generic conceptual model of UK innovative manufacturing (Figure 4.4) through using horizontal evaluation (see Section 3.3.2).

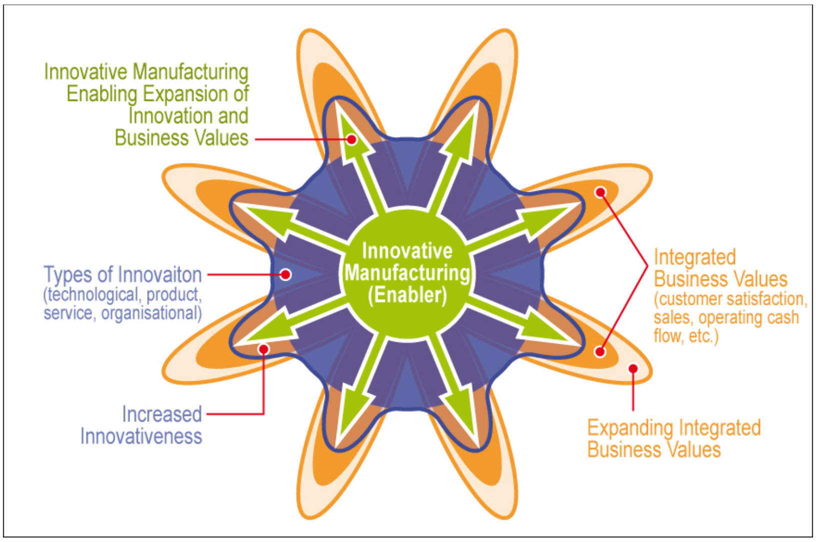


Figure 4.4: Generalised contextual model of UK innovative manufacturing

As innovation becomes one of the most important traits of a successful company (Tucker, 2001), innovative manufacturing as a process is an enabler which utilises different innovation types to increase commercial success. Likewise, an innovative manufacturing company is a commercial organisation in the manufacturing sector which recognises the importance of innovation by continuously introducing new or improved products/services, improving production processes, actively seeking new markets, collaborating with external organisations and improving ways of working (see Chapter 2).

4.2.3 The market and the strength of innovative manufacturing

The survey indicates that the majority of innovative manufacturing companies sell their product on the UK market (85%) followed by 58% in Europe. The lack of export into the emerging economy was apparent (Figure 4.5).

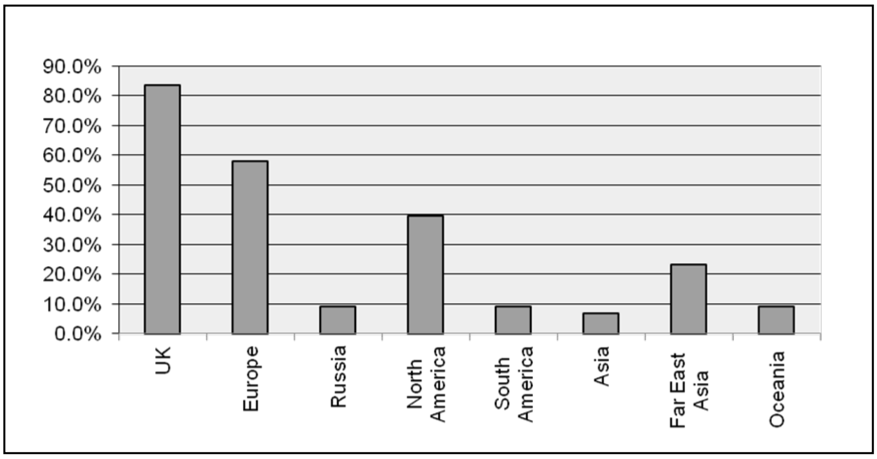


Figure 4.5: Major markets for UK innovative manufacturing companies (Multiple answers), (Questionnaire survey results)

Results of an ISR survey show that many British manufacturing companies have lacked product innovation, quality control and assurance, marketing and delivery, and after-sale service, which have resulted in missing UK domestic demand (ISR, 2003). This result, in conjunction with the questionnaire findings, indicates a discrepancy between general manufacturing and innovative manufacturing in the UK. This can be interpreted as innovative manufacturing companies being competitive in the UK market compared with non-innovative manufacturers. Furthermore, the result immediately shows a potential improvement area for innovative manufacturing companies: to tackle the overseas market (export) more rigorously. This would require companies to increase their competitiveness and other support e.g. better regulations and increased government grants/funding (PWC, 2009), and practical advice and overseas market research (interviewee ME2)

Innovative manufacturing companies' key strengths are identified as the knowledge base (inc. R&D, IP, etc.) of the company (67%) followed by services (50%) and technologically advanced products (23%). The knowledge base and technologically advanced products are broadly similar, where the product is a manifestation of technical knowledge. Furthermore, price was chosen least often as a company's key strength, which concurs with the BIS research findings that advanced technology rather than price is UK manufacturing's strength, which is the competitive strength over the developing countries (BIS, 2010c). Interestingly, just over half of innovative manufacturing companies chose 'service' as their key strength, reflecting the concept of 'Servitization of manufacturing' (Neely, 2007) where manufacturing companies seek to increase their competitiveness through service, for market that price no longer can be a competitive strength.

4.3 Perception and use of design in UK innovative manufacturing

4.3.1 Design utilisation in UK innovative manufacturing

To understand the role of design, especially in association with innovation, one must identify the importance of innovation and design in manufacturing companies. The most important contributor to innovative manufacturing was design (33%), followed by research and technology (31%). The manufacturer interviewees also discussed that design is one of the most important contributors, but they mentioned that the meaning of design is somewhat limited to the 'designing' of a product or service (interviewees ME2, ME4, ME9, ME10 and ME11). This is also further demonstrated by the survey result showing that the majority (75%) of the companies indicating that design is a process by which information is transformed into a tangible outcome. However, just over a third of manufacturers also saw design as a strategic business tool. This is an interesting result as it shows that third of innovative manufacturing companies from the survey felt that the role of design is more prominent in both its voice in key business process decision-making (design strategy), and its influence on the management of a business (corporate-level design thinking). It is a certainly a step up from utilising design at a simplistic activity level (designing), as noted also by the Design Ladder Model by DDC (2003). This indicates that some companies apply design more holistically in their businesses, which is further demonstrated by a manufacturing expert interviewee, where design as a problem-solving process is conducted by company employees from the production floor to marketing and salespeople: "… everyone in the company does something to do with design…" (interviewee ME5). This holistic approach can benefit manufacturers where the company's various knowledge and experiences can be used collaboratively to create products which are both technologically advanced and also meet the customer's needs.

For most manufacturing companies (71%), the expected outcome of design was increased sales, followed by improving brand value (54%), increased profit margin (46%) and cost reduction (46%) (Figure 4.6). This indicates that design is still recognised as a tool to drive the sales of the products the company sell. Interestingly, just over a half of companies now realise that good use of design can improve a company's brand value which was ranked as second most expected outcome of design.

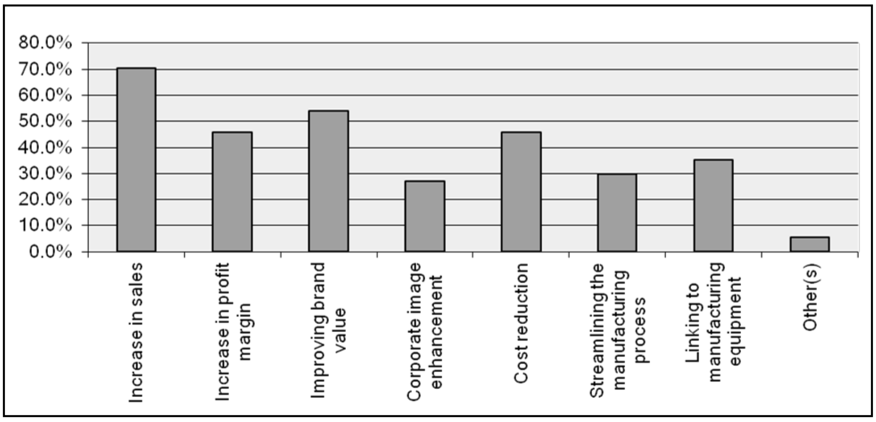


Figure 4.6: Most important impact of design for UK innovative manufacturing companies (Multiple answers),
(Questionnaire survey results)

A Design Council research (2007) indicates that UK businesses using design do so to promote the business to customers and suppliers with corporate communication and branding (50%) and marketing (48%). This contrasts with manufacturing companies' spending on design where Livesey and Moultries (2009) show that the UK manufacturing sector spends 92% of its design resources on technical design, using it for technical and engineering aspects of creating products and services, but only 2% on user design, 4% on promotional design and 2% on identity design. Similar emphasis is noticed with innovative manufacturing companies, where most companies (88%) answered that design is used in new product development and production stages (Figure 4.7) in the manufacturing value chain (BIS, 2010c).

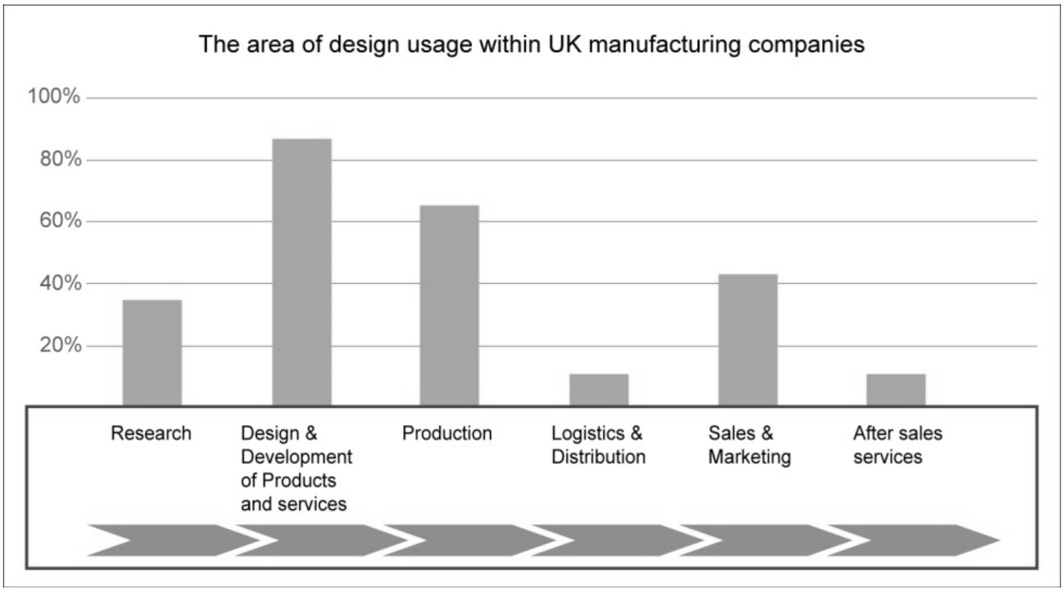


Figure 4.7: Design usage in the manufacturing value chain (Multiple answers), (Questionnaire survey results)

This is further demonstrated by the survey result where, among companies with in-house design practitioners (65%), the overwhelming majority have a role in product design (92%) and/or engineering design (88%). Furthermore, of the companies using external designers/design consultancies, three-quarters use the service one to three times a year, predominantly for new product development (73%), production improvement (27%) and marketing (27%). Innovative manufacturing companies evidently have similar design usage areas (i.e. product, technical design) to those of other manufacturing companies. The research also indicates that major barriers to utilising design were practical reasons such as the cost of design (65%), recruitment of good professional designers/engineers/design consultancies (31%) and software capability/tools to enable design (31%).

4.3.2 Design-driven innovation and UK manufacturing

The survey and interview results indicate that the current predominant use of design in manufacturing takes the form of product/engineering design, used for New Product Development (NPD), a process for creating a product for manufacturing and assembly

(DFM/A). The main purpose of DFM/A is to design for ease of manufacture (production) a number of parts which then undergo an assembly process to become a product (Boothroyd, Dewhurst, & Knight, 2002), However, design is increasingly recognised as ‘adding value’, and used as a strategic tool for the success of businesses as a whole, not just for technical problem-solving activities. The importance of design in creating value for a product and an enterprise is well-documented and understood, and scholars have observed the importance of the relationship between design and business success (Press & Cooper, 2003; Valtonen, 2007).

Howkins (2001) also describes design as being responsible in consumer-facing product/services, and in influencing the whole organisation and manufacturing processes. Verganti (2009) also notes the innovative influence of the expanding role of design, explaining that companies which only use technology-led innovation have limited competitiveness. Companies embracing both technology and design-led innovation can create the unique meaning which differentiates them from their competitors. The product can thus stay competitive longer and have higher sales volume (Verganti, 2009). If design is only used at operational (activity) level as a technical function for production in new product development, as with many UK manufacturing firms, the opportunity will be lost to maximise competitiveness by embracing true innovation potential. This is further demonstrated by Figure 4. 8 which shows the use of design in the UK manufacturing sector placed on top of Verganti’s design-driven innovation process (Verganti, 2009). The figure illustrates that current use of design in UK manufacturing is predominantly in product development (i.e. technical design) whereas the importance of understanding the user through design is heeded by innovative manufacturing (i.e. using user-centred design). However, design-driven research which seeks the radical new meaning in products is missing from innovative manufacturing, and the influence of design in technological research which implies creative user-centred design approach in technical R&D (see Section 4.3.3). Although Verganti’s model deals with design-driven innovation mainly for products with radical innovation, it shows the lack of use of design even in the innovative new product development process.

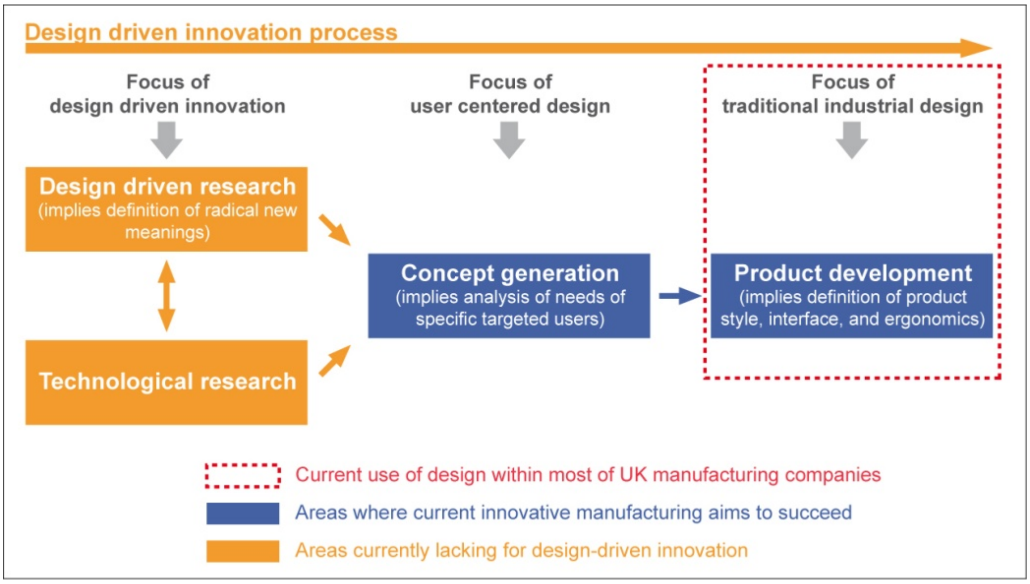


Figure 4.8: Design-driven innovation and current use of design in UK manufacturing sector. Adapted from (Livesey and Moultrie, 2009, Verganti, 2009:173),(Questionnaire survey results)

Design can be used as a strategic business tool by adopting design thinking. Design thinking as described by Martin (2009:7) enables companies to create "breakthroughs that move the world forward", echoing Verganti's expression of creating meaning through design-driven innovation. Creativity and innovation are thus encouraged in both the product/service and in corporate culture. The National Endowment for Science, Technology and the Arts (NESTA, 2008a) recommends that companies should embrace hidden innovation. Brown (2009) describes practical design thinking as creating a harmonious balance between three competing constraints in a company: feasibility, viability and desirability. Design thinking thus influences both the management of a firm as a whole and creates competitive products for the complex rapidly changing market. Design-driven innovation and design thinking are especially relevant to UK manufacturing, because the research found current advantages in technological innovation and capabilities by UK manufacturing at global level. Harnessing design gives manufacturing a greater chance of surviving hostile competition and thriving in the future.

4.3.3 Design issues for UK innovative manufacturing

The in-depth interviews with manufacturing experts provided further insight about current design issues in UK innovative manufacturing, including (i) how innovative manufacturing companies use design more holistically in a business, (ii) the challenge of design's influence on corporate-level decisions, (iii) limited problem-solving activity for bespoke B2B products, (iv) a lack of desire and resources to expand the market by using design, (v) the absence of design in R&D, and (vi) limited awareness of the benefits of design. These issues are directly related to various aspects of innovation. The in-depth interviews revealed that although innovative manufacturing companies excel in product innovation, process and organisational innovation remains underutilised, especially by SMEs. Similarly, business management thinking largely ignores the use of design as a strategic tool which can enable the company to become more innovative. According to the manufacturing experts (interviewees ME2, ME5, ME6, and ME10), this may be due either to a lack of understanding of the influence of design, or of company resources, leading to scepticism about the value of design.

Shared responsibility for design

Interviewee ME2, a manufacturing expert who is also the Managing Director of an innovative manufacturing company, commented, “There is no separate ‘design function’ within the organisation, but NPD, user research and idea generation are all the shared responsibilities of the all employees.” A design output requiring technical ability, such as graphic design skills for a brochure, may be conducted by design practitioners, but the company as a team shares responsibilities for design from research, idea generation, development, production process to sales and marketing and after-sales service. Each employee has a special business function (production, sales, etc), but the team approach demonstrates the use of the term design in a more holistic sense across the manufacturing business, as discussed earlier this chapter. Interviewee ME2 commented that this is possible in a small agile company, where it creates a sense of engagement for the products they sell and makes the working environment more creative where new ideas are regularly considered and discussed. This was evident in another company, specialising in bespoke products for special industrial applications (interviewee ME5), where this level of engagement is encouraged, to find the best idea to solve a problem, to meet the client’s specifications. Neither company employs full-time design practitioners or design managers, but they encourage creative problem-solving by collaborating both internally with finance, management, and production experts, and without specific design disciplines (product, graphic design etc.,). These innovative manufacturing companies acquire the necessary skill sets of design professionals through external collaboration, hiring design practitioners to oversee the design process, and provide technical design skill sets unavailable in the company.

Design professionals as business advisors

Interviewee ME3's innovative manufacturing company has used an external design consultant for fifteen years who both consults on the product/engineering design technicalities and shares his opinions about how the business can increase competitiveness by consulting on company product innovation processes. This small-scale process contains only a few steps as the design professional deals directly with the managing director, who has great trust in the design professional's ability to produce market-leading products. Designers also work as problem-solvers in Interviewee ME2's company, where the external designers have a prominent voice in decisions about new products to be developed by the company. In contrast, in some larger companies (interviewees ME7, ME9 and ME11) with much more structured businesses, design plays a lesser role in strategic decisions on development of products. In a more rigid environment efficiency may be high, reflecting their production plants, but design professionals have limited influence in the company, their role restricted to the technical aspects of a product. Some large companies allow design a voice in management decision-making process (interviewee ME9), in the form of a design manager, but not on a par with the directors, so it is difficult for design to influence management decisions at corporate-level.

Limited problem-solving activity in bespoke and B2B products

Companies producing successful bespoke and B2B products inherently excel at problem-solving the clients' specific set of problems (interviewees ME2, ME4 and ME5). They act as almost like a consultant engaging with their client, much as a design agency would, discussing the client's requirements to provide solutions to fit the product. This ability is seen as their most important competitive advantage in their given market. Knowledge – in the form of employees' experience and technical abilities to produce a desired outcome - is a key element in achieving the result. However, in such cases, the ability of design research to obtain a wider perspective of both market and users is limited if the company relies solely on solving clients' problems. The company's design activity may be passive and technical, with less creativity applied to the products or service. Although this may help innovative manufacturing companies to ‘sell’ their products/services (Martin, 2009), it can also make the company too reliant on its analytical thinking, rather than balancing it with intuitive thinking to drive true innovation. Some companies try to exceed the clients’ expectations by providing extras e.g. in packaging and materials choices (interviewee ME5), simplified components (interviewees ME2 and ME3), and providing advice on the changing market (interviewee ME2), to increase their competitiveness, but it is generally difficult to improve on clients’ specifications. This becomes more apparent where the product is within a complex supply chain, because even a small change in a product property can have a knock-on effect on the entire supply chain (interviewee ME9).

Expanding the market

There is broadly a lack of any proactive approach to expanding the market because manufacturing companies simply do not see the benefit of doing so when their business performance is satisfactory (Interviewee ME5). Once they are in the supply chain for larger manufacturing companies, they tend not to explore new markets (Interviewee ME8). However, the drawback to this passive approach is that when there is increased competition it is extremely difficult to survive. These companies are usually the specialised and leaders in their sector, with a long history of several client relationships, and are thus more relaxed about increasing their competitiveness through innovation, and even less likely through design. Innovative manufacturing companies’ desire to expand the market increases slightly when they actively collaborate with external organisations to expand their capabilities (interviewees ME5 and ME8). However, the lack of design utilisation remains, even when trying to understand a new market and its users, one of the most important role of design research which increases the chance of success in a foreign market (Hertenstein and Platt, 2001, Cooper and Evans, 2006, Sawhney and Prahalad, 2010, DC, 2015). This is also hindered by limited staff and financial resources (interviewee ME2) especially for overseas markets.

Absence of design in R&D

Companies with their own R&D department tend to excel in new product development by producing better products for their customers (interviewees ME6, ME9 and ME11).

However, their approach to innovation can be limited when developing new technologies, either internally or in collaboration with outside institutions (i.e. universities, supported by government grants). The role of design in R&D is often limited or even absent, as the scope of design is the activity to style a product and enable production (engineering design) rather than to provide user and market insights to increase the chance of success in R&D (interviewee ME9 and ME11). This is one of the most apparent area showing the limited use of design. Despite support through "Design Option" by Innovate UK (formerly the Technology Strategy Board, TSB) (TSB, 2012a) for companies to use design advisers in R&D processes, almost all the manufacturing expert interviewees reported the lack of design utilisation in this area. This was attributed to a lack of awareness of how design can be holistically integrated into all areas of business, to identify problems from the user/client perspective. This powerful empathic thinking process, described earlier in Section 4.3.2, will enable innovative manufacturing companies to make R&D outcomes more commercially successful.

Limited awareness of the benefit of design

The questionnaire results show that even for innovative manufacturing companies design's role is limited as a true link between creativity and innovation, where innovation includes technological, product/service, process and organisational innovation (see Section 2.3). Some company interviewees demonstrated the concept of 'silent design' (Gorb and Dumas, 1987) where design is considered as a shared responsibility even among non-design professionals throughout a company (interviewees ME2 and ME5). The perception of design remains predominantly limited within the boundary of 'designing' where it is only utilised in NPD as a technical function of a company (Interviewees ME6, ME8, ME10 and ME11). The reasons for this limited awareness include: (i) top-level managers do not have time to engage in creative activity to develop better business management practice (interviewee ME5), (ii) limited employee resources and complications in applying design as a strategic tool (interviewees ME2 and ME6), and (iii) scepticism about using design as a tool to develop and better manage a business (interviewees ME5 and ME9).

Technical design serves UK manufacturing companies well, as the UK is amongst the most capable countries, producing excellent designs for both form and function. However, UK manufacturing's use of design is limited as described by both Cox (2005) and Liversey and Moultrie (2009). This is echoed in the UK's innovative manufacturing companies, where utilisation of design is similar to that in the general manufacturing sector, opinions about design mainly limited to technical design. Some companies practice creative problem-solving in their business practice, which shares characteristics of design as a problem-solving process. However, they are still limited to problems in an NPD process. Lack of interest in creative business development, whether due to limited resources or desire, contributes to limiting the greater role design can play to enable innovative manufacturing companies to further increase innovativeness across the company, to increase competitiveness both domestically and globally. The questionnaire survey research found manufacturing companies receptive to the importance of design, albeit technical design – a potentially good starting point for encouraging them to fully embrace the advantage of design throughout the company.

4.4 Chapter Summary

This chapter used the findings from exploratory interviews with manufacturing academics, a questionnaire survey with innovative manufacturing companies, and in-depth interviews with manufacturing experts, to identify and analyse the innovative manufacturing context, its perception and use of design, and issues about the role of design.

The results indicate that innovative manufacturing is an enabler for advanced manufacturing to expand into high-value manufacturing. This theory was then used to develop a more general contextual model of UK innovative manufacturing, showing how innovative manufacturing enables a company's innovation to increase integrated business values including customer satisfaction, sales, operating cash-flow, etc. The questionnaire survey also revealed that UK manufacturing's strengths are knowledge and service, and price was predictably not considered a strength by the majority of the companies.

Design is considered important by the overwhelming majority of innovative manufacturing companies, who also regard it as the most important contributor to innovative manufacturing, followed closely by research and technology. However, design perception remains largely about technical design, as with general manufacturing companies, indicating limited use of design and its capabilities by innovative manufacturing companies. The research explains the importance of design for innovation where the concept is of design-driven innovation and design thinking. It also shows continuing lack of design utilisation in the early stages of the design innovation process, and as a philosophy to increase creativity and user understanding for management of a company. Although the research also identified some examples of design as the shared responsibility of all employees (a holistic approach), and as a business development channel (business advisor), overall design is not being fully utilised in UK innovative manufacturing companies, and its capacity to expand various types of innovation remains poorly understood. Hence, to improve the understanding of the full areas of design to increase company's performance through innovation, a comprehensive overview of design that is closely related to increasing competitiveness and company growth is required. The next chapter discusses an overview of the relationship between design and innovation, using the findings of literature reviews and expert interviews. A design innovation spectrum will then be created to demonstrate the capabilities of design for innovation in the business context.

Chapter 5. Design Innovation Spectrum

5.1 Introduction

Chapter 4 discussed innovative manufacturing in relation to high-value and advanced manufacturing, which are the UK government's strategic emphasis, and created contextual model of innovative manufacturing in relation to types of innovation and integrated business values. It also addressed the perception, role and utilisation of design by UK innovative manufacturing companies. The research indicates manufacturers' narrow view of design, which leads to a subsequent lack of utilisation of design as a strategic tool and an agent to enable creativity to enhance innovativeness. In order to provide a comprehensive view of design and its relationship with innovation, literature reviews were conducted of academic papers, books, reports with a particular focus on types of design and innovation and on the relationship between design and innovation. A synthesis of the literature findings resulted in the formulation of both the design spectrum and the innovation spectrum, and the subsequent fusion of the two spectrums resulted in the construction of a design innovation spectrum.

Table 5.1: Brief index of design innovation expert interviewees and their groups

Interviewees	Organisation (groups)
DE1, DE2, DE3, DE4, DE5	Design Consultancy (DP)
DE6, DE7, DE8	Design Promotion and Support Organisation (DO)
DE9, DE10, DE11	Governmental Innovation Support Organisation (IO)

The design innovation spectrum was evaluated through the expert interviews to identify potential issues, omissions or misinterpretation to further develop and finalise it. The interviews were conducted with eleven design innovation experts (Table 5.1) using the semi-structured in-depth method. In order to identify the relevance of the design innovation spectrum in the innovative manufacturing context, a case study was then conducted of forty six innovative manufacturing companies: twenty two design-oriented award winners and twenty four innovation-related award winners. Secondary research was conducted - of literatures from the awarding body, promotional literatures, websites and news/magazine articles, interviews and of the companies' social media (LinkedIn) - to identify the practical implications of each area of the design innovation spectrum (see Chapter 3 for research method details). In this chapter, the findings and subsequent discussion of the result of analysis will be discussed as shown in the chapter map (Figure 5.1).

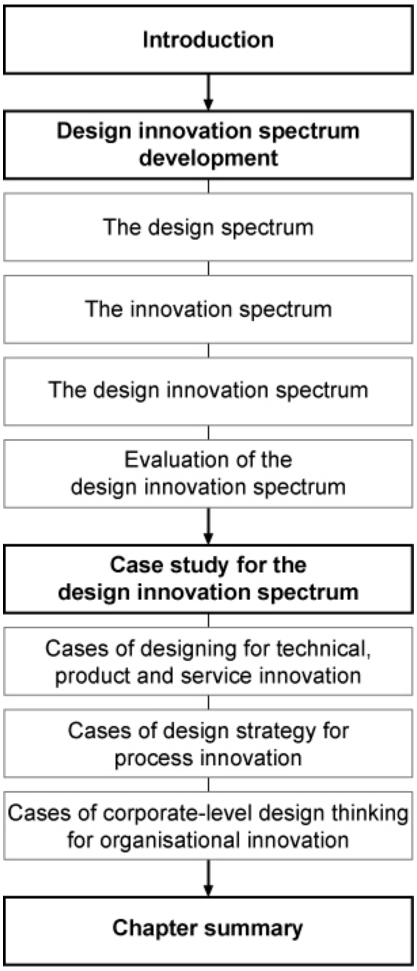


Figure 5.1: Chapter map

5.2 Design innovation spectrum development

5.2.1 The design spectrum

The research revealed that it was difficult to define the parameters of design, which has variable forms. It sometimes describes an activity used to produce an object e.g. design for manufacture and assembly (Lindbeck, 1995, Boothroyd et al., 2002). It can also describe a creative process adopted by a designer or managers to generate the preferred outcome through intangible input, i.e. a business model, innovation process, company structure, and even company vision and strategy (Blaich, 1988, Mozota, 1990, Best, 2006, DC, 2007, Sawhney and Prahalad, 2010, DC, 2012a), and may include Simon's statement that "everyone designs who devises course of action aimed at changing existing situation into preferred ones" (Simon, 1996: 111). This complex array of meanings discourages manufacturing companies from embracing design more systematically and as a strategic tool for their business because it can be seen as resource-intensive in a commercial environment. The design spectrum has been created to clarify the wider contribution of design in businesses in a more accessible form. The effect of design can be broadly divided into two: i) influencing the production and delivery of the product/service, and ii) influencing the management of a company. The definition and usage of design varies depending on different points of view, so a comprehensive review was conducted of the meanings of design in the commercial sector of literatures from design, business management, government and non-government organisations, to enable a more intuitive understanding of design.

In order to enable a whole-company application of design at all levels of manufacturing companies, a theoretical design spectrum model was created by synthesising the key elements found in the literature review in Chapter 2. Although this attempted to extract the elements of design to clarify the parameters and meaning of design, it is still difficult to understand, not least because authors define the same terms differently. Nevertheless, the elements of design are identified as 'designing', 'design strategy' and 'corporate-level design policy'. Designing represents design as a part of company activity to create an artefact or service, including designing for manufacture and engineering design. Design strategy is the management of design in a company, typically led at strategy level by design managers or senior managers. This includes managing process improvements - the designing process, the production process, the logistic process, the material handling process etc., - to enable design to align with corporate strategy. Corporate-level design thinking is described by many design-oriented practitioners and theorists. However the 'corporate-level' is suffixed to eliminate confusion about design thinking for all design activities - and is specifically for the management of the business as a whole, usually adopted by the top-level management of a company to increase creativity and a user-centred approach to business problem-solving. The various design areas are represented on the top row of the design spectrum model (Figure 5.2).

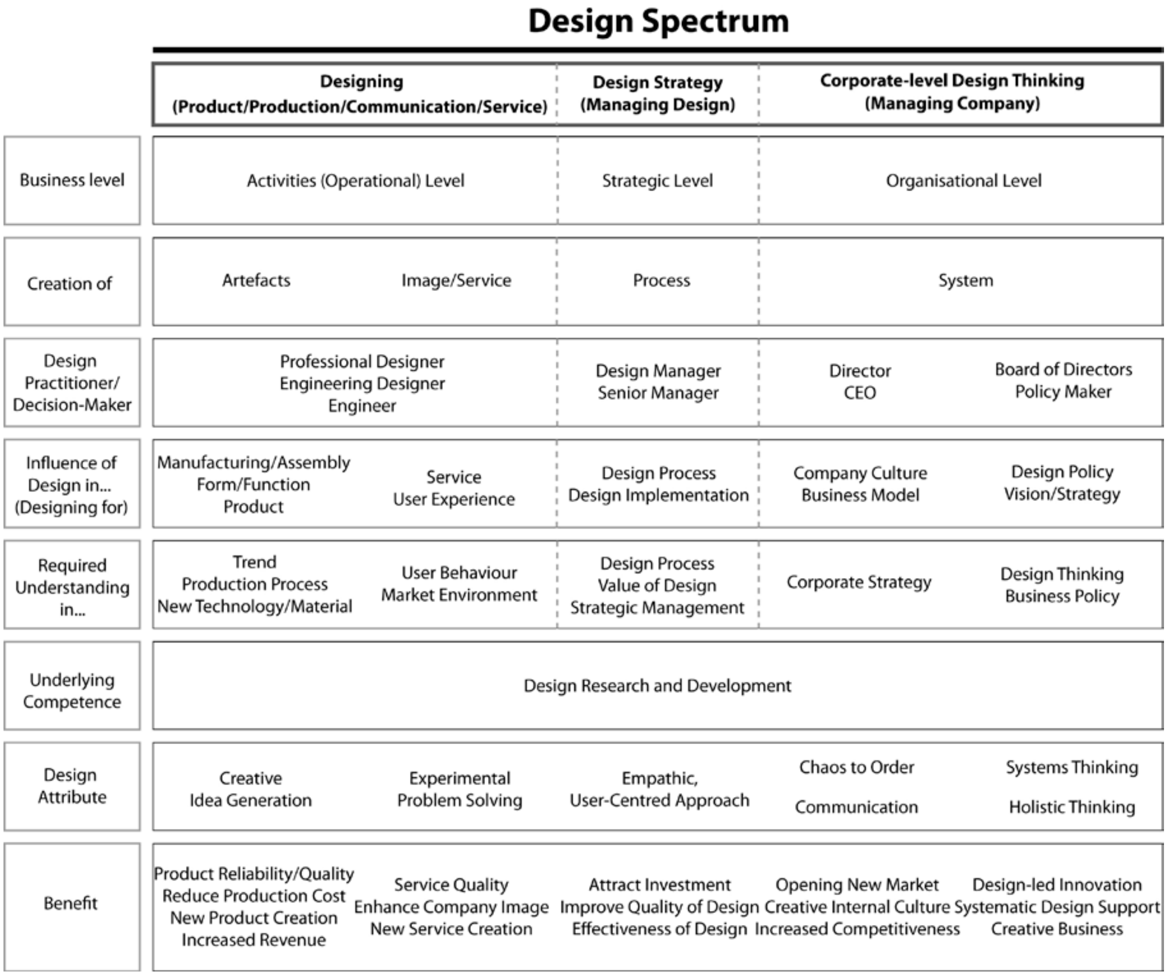


Figure 5.2: Theoretical model of the design spectrum with key terminologies to describe its context in business.

The design spectrum does not flow only from left to right: the design areas function independently without requiring competence in other areas in order to be practised in a company. This is similar to the non-linear design innovation process described by Kumar (2013), who explains how a design project can start at any stage of the process and fill in the necessary requirements as required. The staircase model used by the DME award (Kootstra, 2009) which describes the stages of design management working like a 'staircase' to increase the level of design management competence, whereas in the design spectrum in this research the areas of design resemble an array of closely interlinked aspects which need to be addressed but not in sequence. Dotted lines are therefore used to describe the loose distinctions, because it is hard to establish the distinction between the design areas, which are closely linked and sometimes interdependent.

The design spectrum attributes listed in the left-hand column are derived from various literatures to best describe the areas of the spectrum. Although they are sometimes hard to distinguish, some general patterns emerged from the literature. The ‘business level’ described earlier in chapter 2 indicates the possible place of design in an organisation, and the ‘creation of’ indicates the possible outcome or improvements through using design. ‘System’ is mentioned in some literatures (Gorb, 1986, Best, 2006, Clark and Smith, 2008, Brown, 2009, Visser, 2009) in the context of the company as whole, not just as a system for a specific product or service (Boothroyd et al., 2002, Bruce and Bessant, 2002a). The ‘design practitioner/decision-maker’ refers to the people in an organisation most likely to be directly responsible for particular areas; similarly the ‘influence of design in... (designing for)’ indicates the functions and context of a business which these design decisions will influence. Furthermore, ‘required understanding in...’ describes areas of knowledge and awareness required to make appropriate decisions. These areas of understanding are not exclusive to professionals of particular design areas e.g. a good understanding of trends, production processes, user behaviour etc., - which are in the ‘designing’ area of the spectrum - are also required by company directors. However, the separation indicates that these areas of understanding are essential for ‘designing’ a good product/service and user experience, just as understanding corporate strategy, design thinking and business policy are essential in corporate-level design thinking. Similarly, ‘underlying competences’, ‘design attributes’ and ‘benefits’ are even harder to separate, so the dotted lines are removed from these attributes of the design spectrum.

5.2.2 The innovation spectrum

The importance of innovation is emphasised in almost all socio-economic areas (Baregheh et al., 2009). In order to more easily comprehend the various areas of innovation, an overview was created to enable better understanding of a parameter of innovation in a company. The Innovation Spectrum was thus created, which contains the various theories of innovation including, but not limited to, the Technology readiness level (TRL), the related innovation model by TSB (2012b) for its relevance in the manufacturing sector; the

Innovation Value Chain (Hansen and Birkinshaw, 2007) and "Total Innovation" (Roper et al., 2009) for its overall perspective on innovation in both theoretical and government level perspectives; and Ten Types of Innovation (Keeley et al., 2013) for its practical implications for businesses with a plethora of case studies easily recognisable in the commercial context. In the Ten Types of Innovation model, the "offering" consists of a company's main products/services, "experience" includes customer-company relationships, and "configuration" comprises a company's internal workings and business system.

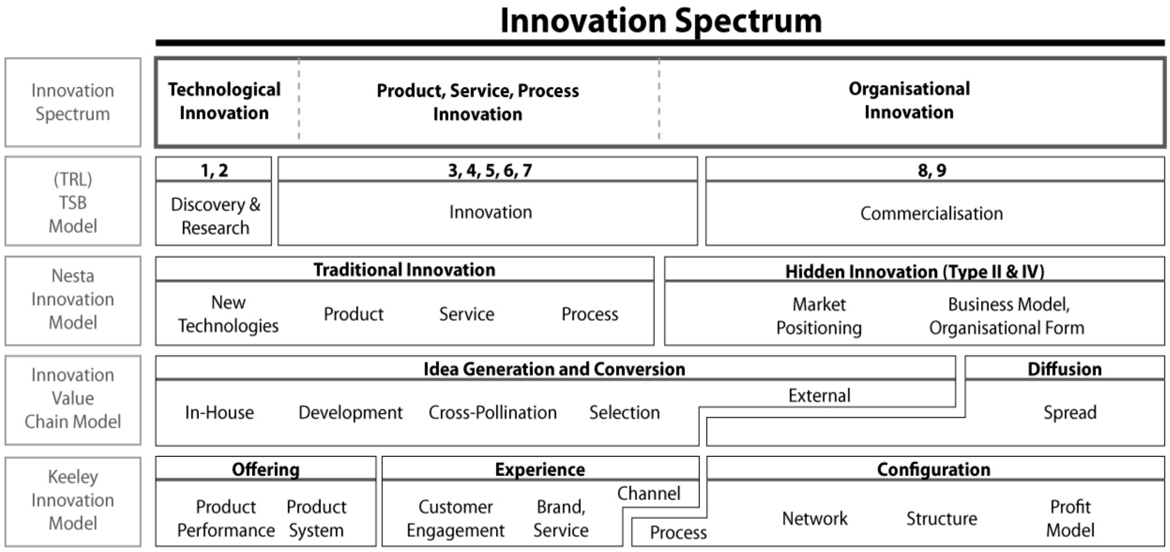


Figure 5.3: Innovation spectrum to illustrate the parameters of innovation within a company

The innovation spectrum is constructed differently from the design spectrum because although it can sometimes be as elusive as design, research into innovation has found it is much more established and structured. Despite a tendency to over-focus on technological innovation in the manufacturing field, in a management or marketing context the view of innovation was much more comprehensive. The main areas of the innovation spectrum were found to be technological innovation, product service and process innovation, and organisational innovation. As with the spectrum areas, they are strongly interlinked as with the design spectrum, but for the purpose of this holistic overview it was necessary to separate these areas. According to NESTA's total innovation theory, technological, product, service and process innovation can be categorised as traditional innovation, which concurs with the more manufacturing-oriented theories of innovation (Mosey et al., 2002, Laforet and Tann, 2006), whereas organisational innovation includes what NESTA describes as “hidden innovations”, and other theories which deal with the broader perspectives of innovation in an organisation (Utterback, 1986, West and Anderson, 1996, Berkhout et al., 2006). It is not intended as a process to be read from left to right; although TRL (NASA, 1995) and Innovation Value Chain Models are process-based, sometimes not all aspects of those models are applied to produce and sell a product or service, e.g. some products are launched with consideration only of “traditional innovation” areas of the spectrum. They meet the requirements of TRL 1-7, where appropriate. However, this “partially innovative” product will have a reduced chance of success because of the lack of consideration of all areas of the Innovation Spectrum. Some models, including the Innovation Value Chain and Ten Types of Innovation, were de-constructed to best fit the overall innovation spectrum (Figure 5.3).

5.2.3 The design innovation spectrum

The relationship between design and innovation can be found in several literatures, and it is harder to find a text that does not associate design with innovation. However, the scope of design and innovation varies and the association also differs depending on the literature. The research found three main ways in which design is related to innovation. Firstly, it provides a “symbolic representation” as a vision for innovation (Swann and Birke, 2005), which is closely linked to design’s capacity to visualise ideas. Secondly, it creates greater meaning for the innovative products and services it delivers (Trueman and Jobber, 1998, Verganti, 2009). Lastly, it underpins how a company, as a whole, creates and maintains innovation itself through its operational and strategic management (Mozota, 2003, DC, 2014). An important ingredient of all of the listed associations between design and innovation is design’s ability to manipulate and visualise creativity to solve an organisation’s complex or “wicked” problems at different levels of the organisation. A DTI report illustrates this, describing design as a bridge between scientific knowledge and new technology to produce a usable end-product, emphasising that it links creativity and innovation (DTI, 2005). However, in this report design is still seen as activities within a business i.e. the disciplines of graphic, interior, fashion, industrial and engineering design. When design is seen as an activity (on the left-hand side of the design spectrum,) design will inevitably be only a portion of the innovation spectrum, with areas of innovation outside of design’s influence (Walsh, 1996).

Cox adopts the influence of design in the broader innovation spectrum (2005). He uses a definition of design similar to that of the DTI, also referring to the Third Community Innovation Survey to illustrate that design expense can indeed generate greater innovation impact in i) an increased range of goods/services, ii) improved quality of goods/services, iii) open new markets/increased market share, iv) improved production flexibility, v) reduced unit labour costs, and iv) reduced materials and/or energy. Furthermore, design's influence can be seen across various areas of manufacturing SMEs and, as Tether (2009) describes, firms using design in both products and services are more likely to produce good products and process innovation, although his reference to design was more about explicit design (towards the left-hand side of the design spectrum) rather than "silent" design (towards the right-hand side of the design spectrum). Design parameters in these reports concentrate on confining design in a form which is regarded as a part of the firm's activity. This is predictable, since it is more manageable to measure than that of corporate-level design thinking. However, a theory from Verganti (2009) elaborates design further by recognising that it can change the meaning of an object, and furthermore of the company producing it. Although he sees innovation in relation to technology, this view of design influence demonstrates the broader importance of design in relation to innovation. Mozota (2003) expands this further, taking design to corporate-level, where it can influence changes in the vision and strategy of a company itself, which is where innovation is also seen as an essential part of success.

The latest design-thinking theories also discuss design at corporate-level and include design influences for organisational innovation (Bertola and Teixeira, 2003, von Stamm, 2008, DC, 2011, Battistella et al., 2012, Mootee, 2013), but it becomes much harder at this point to distinguish and measure design input in an organisation. When the parameters of design and innovation are regarded as having an influence on the whole organisation (Figure 5.2 and Figure 5.3), it is theoretically possible to overlay them with regard to their relative capabilities, and by constructing this fit between design and innovation provide a comprehensive overview of design capabilities which is likely to influence innovation in particular areas and levels of businesses (see Figure 5.4).

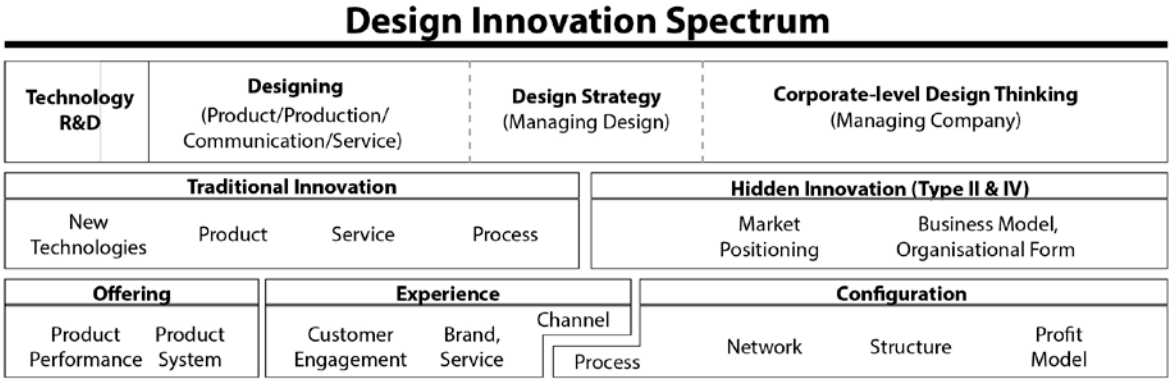


Figure 5.4: Initial design innovation spectrum presented for expert evaluation

5.2.4 Evaluation of the design innovation spectrum

Expert interviews to evaluate the viability of the design innovation spectrum were conducted with design innovation experts including professionals from design consultancies (DP group), design organisations (DO group) and governmental innovation supporting organisations (IO group) as shown earlier in this chapter (Table 5.1). The interviewees were presented with the design spectrum (Figure 5.2) and the innovation spectrum (Figure 5.3) to provide the background of the design innovation spectrum, and were asked to discuss the viability and feasibility of the design innovation spectrum (Figure 5.4) to identify possible issues and improvement areas to finalise the design innovation spectrum.

Evaluation of the design innovation spectrum by the expert interviewees revealed that it was comprehensive enough to show most of the influences and roles of design in a firm. This was especially apparent with the DP and DO groups, where all agreed that Corporate-level Design Thinking is a positive inclusion in the spectrum, to demonstrate the importance of design in business management. The IO group also recognised the design innovation spectrum as a good approach to address the "fuzziness" of the term "design" in manufacturing companies. However, the IO group and some interviewees from the DP and DO groups (interviewees DE1 and DE7) also recognised that including all the design areas in the spectrum could lead to confusion about what design signifies for a company. They also noted that it could be overwhelming for manufacturers with little knowledge of, or worse still little interest in, design to relate to all the areas of design, especially towards the right-hand side of the spectrum (interviewees DE1, DE2, DE4, and DE7). This observation reflects the limited recognition of design by manufacturing companies (discussed in Chapter 4, and by Na and Choi (2012)), and explains why the link between design and innovation in the design innovation spectrum is important, as it attempts to illustrate the relevance of the expanding role of design to “total innovation”, which manufacturing companies are more familiar with.

Some interviewees misinterpreted the design innovation spectrum, their confusion arising mainly from over-simplification of the spectrum. Firstly, most interviewees saw the spectrum as a left-to-right process; this was unintentional as it is constructed to show the parameters of Design Innovation for different levels of a whole business, not as a linear process a company must go through to achieve better innovation. This confusion, arising from unclear representation, was addressed by including areas of decision-making influences by design practitioners (white) and top managers (grey) (see Figure 5.5), which also addressed the issue of representing the amount of involvement in each design innovation attribute by the people in an organisation (interviewees DE2, DE3, DE5, DE7 and DE8). For example, in the “Where (Business level)” attribute, the design practitioner’s involvement is more at an activity level, whereas the top manager’s involvement is more at organisational level. Furthermore, although interviewees DE1, DE2 and DE10 suggested that the spectrum itself should be visually simpler to give immediate effect to an appropriate audience, most interviewees found it difficult to easily associate the attributes of the design spectrum (see Figure 5.2) and the innovation spectrum (Figure 5.3) in the design innovation spectrum (see Figure 5.4), as they are omitted to give a simpler visual representation. Some details were therefore presented again in the improved design innovation spectrum (Figure 5.5). The spectrum attributions also used a more recognisable analogy (the Kipling method), in response to a suggestion from DE1, DE4, DE5 and DE11.

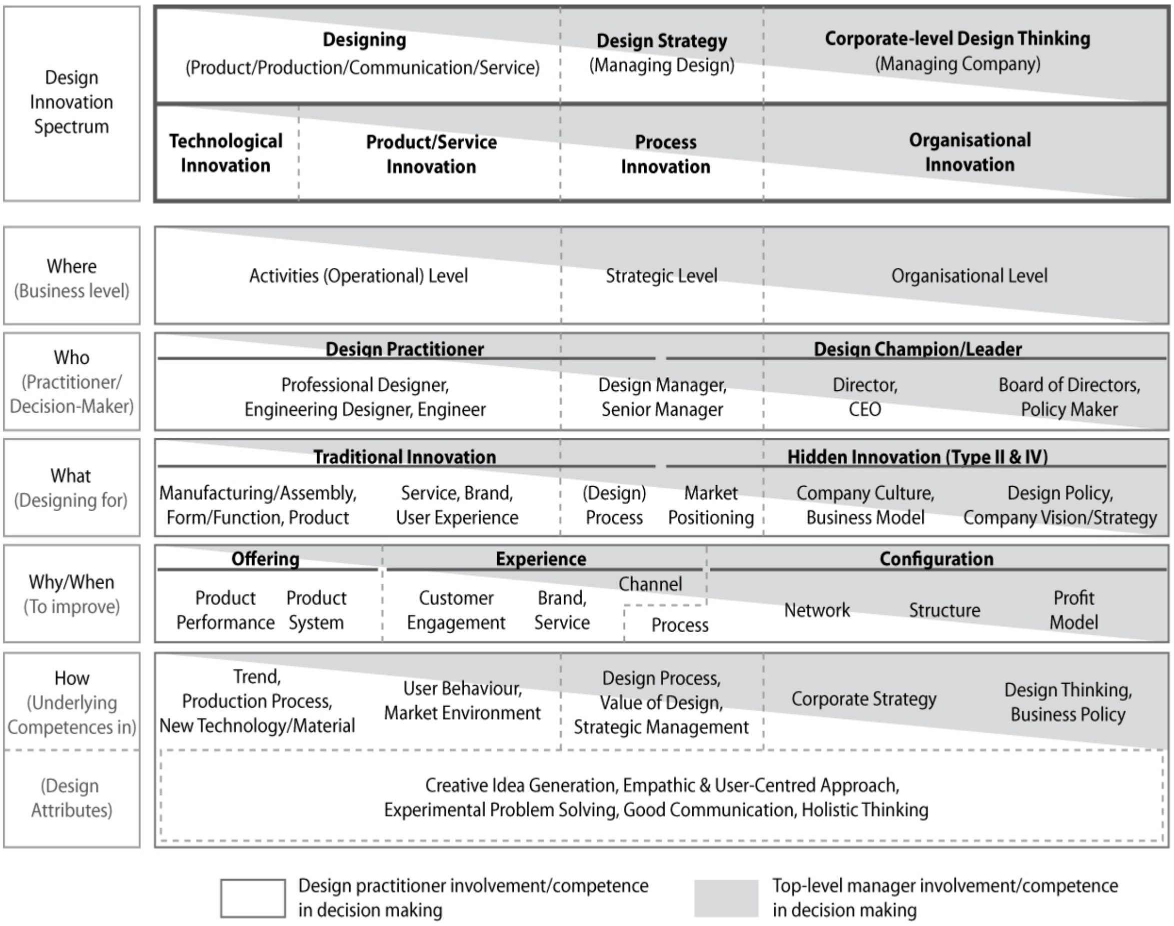


Figure 5.5: Design innovation spectrum with improvements suggested by the experts in design and manufacturing

The DP and IO groups made contradictory comments: the IO group all agreed that design has little or no effect on technology R&D in a pure science form (TRL 1-2). However, DE2 and DE3 commented that design should touch on this, even in this early stage of innovation, not as a new product development tool per se, but as a way to understand the need to consider which areas of R&D are required, and to develop a company culture or environment which values creativity in the technology development. However, the DP group also recognised that this is not practised in the real world, as it is seen as an unnecessary risk and resource intensive (interviewees DE1, DE2 and DE6).

This was also a general comment from the DP and DO group, where in an ideal situation it would be best to practise all areas of the design innovation spectrum, but it was felt there are many barriers to achieving this. They recognised, from their experiences, that there must be a strong need in a manufacturing firm's senior management to adopt changes in design or even innovation, such as decreasing sales and market share of product(s), or increasing competition and diversification of the product range etc., Even with these needs, some interviewees (interviewees DE2, DE4, DE6 and DE7) had difficulty convincing senior management to appreciate and use the expanding roles and capabilities of design, as with the design innovation spectrum. DE9 and DE10 agreed, saying that design was firmly situated in technical design (designing) and they had seen no improvement in viewing design as widely as in the design innovation spectrum.

The research found three ways to increase acceptance of all the areas of the design innovation spectrum. Firstly, the presence of a design champion or leader in a company, discussed by almost all interviewees, was cited as one of the key elements missing from the initial design innovation spectrum, which is added in the “Who” attribute in the revised design innovation spectrum. This role is not normally taken by designers, but by senior managers in manufacturing companies who are willing to take risks to use design more widely in a company, e.g. using corporate-level design thinking to improve the business model, and even the company vision and strategy. The second method the experts have used was building trust in design by succeeding and exceeding expectations with smaller “activity level” projects (DE2, DE4, DE5, DE7, DE8 and DE11) and convincing senior management or the CEO that design can contribute more in the company’s strategic and organisational levels. Thirdly, an indirect way of attracting interest for the whole design innovation spectrum is to use success story case studies. This was often used by the DO group as an initial method to explain the use and benefits of design at different levels and in different situations in a business (DE6, DE7 and D8).

Further discussion of the design innovation spectrum included the confusion for interviewees DE3, DE4 and DE5 over whether it represented all the elements (input) of innovation, which was unintentional as it aims to show possible ‘design’ influences on innovation. Other operational areas in business - marketing, HR, and environmental areas of business such as government policy, regulations and abrupt changes in the market - all influence innovation. Design is therefore not an exclusive contributor to innovation, but the design innovation spectrum shows that it certainly can influence all areas of total innovation.

5.3 Case study for the design innovation spectrum

The practical implications of the design innovation spectrum were studied by using case studies of innovative manufacturing companies, recognised for their innovativeness through various awards. These awards include the Design Management Europe (DME) Award, dba Design Effectiveness Award, the Queen’s Enterprise Award (Innovation Category), and The Manufacturer MX Award (innovation and design category). These awards are carefully selected to represent the balanced perspectives of design and manufacturing (mainly engineering) on manufacturing companies. Cases from The Design Council’s Designing Demand Programme were also included because they provide a comprehensive overview of the benefit of design in UK manufacturing companies (see Chapter 2). Forty six cases were studied, twenty two from design-related awards or programmes, and the other twenty four from business (innovation) or manufacturing awards. The manufacturing companies identified from these initial sources were then further investigated for company history, culture, processes, influences in the market, philosophy of the top-level manager (CEO, managing directors etc.), and success stories of design innovation (problem-solving) in order to understand and predict the use of areas of the design innovation spectrum. As the research used secondary sources for the case study, the descriptions and examples may not represent the activities, processes or philosophy of the overall company. Some companies provided insights using multi-channels including interviews, blog-posts, promotional videos, etc., whereas others provided limited information on their activities and processes. However, the case study provides an overview of the practical implications of the design innovation spectrum for innovative manufacturing companies.

The benefit of using ‘design’ in a manufacturing company is apparent through cases identified from the design-related awards and from The Design Council. Similarly, the benefit of ‘innovation’ is explained through companies which have won manufacturing-oriented awards. Furthermore, by analysing the manufacturing companies, the research found elements of design innovation, even where the company does not use the specific term ‘design’ in their promotional materials and websites. The cases are thus categorised using the description of the areas of the design innovation spectrum: (i) ‘designing’ and ‘technological/product/service innovation’ which are the activities of a company to create artefacts or viable services to be launched in the market for specific set of target customers, (ii) ‘design strategy’ and ‘process innovation’, which encompass strategic level decisions to manage and/or create design and innovation processes in order to increase efficiency, feasibility and collaboration, and (iii) ‘corporate-level design thinking’ and ‘organisational innovation’ which include the creative management of an entire organisation and its business model using user-centred approaches with clear vision from top-level management or fully supported by them financially and authoritatively.

5.3.1 Cases of designing for technical, product and service innovation

The manufacturing companies identified in this section produce exemplary products which are regarded as innovative because of their financial success (dba Design Effectiveness Award and Queen’s Award for Enterprise) and by the experts in design and manufacturing (DME Award, Design Council’s Designing Demand, EEF Award). Table 5.2 provides a list of selected companies which demonstrate the presence of ‘designing for technological, product and/or service innovation’ which produces successful products/services in the market. The range of products manufactured by the companies vary greatly, from consumer products (Bolin Webb, KANO Computer Kit, BT Hub, Yorkshire Flower pot, Surgu, Linn Products, Tangle Teezer, etc.) to industry-specific, business-facing products (Thrislington Cubicles, Touchline Flags, Acro Aircraft Seating, James Heal, Irisys, Pryor Marking Technology, etc).

Table 5.2: List of companies that demonstrate the ‘designing for technical, product and/or service innovation’ area of the design innovation spectrum

Origin of the Case	Manufacturing Companies
DME Award	Nightingale Care Beds, Thrislington Cubicles, Performance Health Products,
dba Design Effectiveness Award	KANO Computer Kit, Touchline Flags, BT (Hub), BT (Phone), Lovair, Reckitt Benckiser (Lysol Dettol), Acro Aircraft Seating, Unilever (Project Rainbow)
Design Council Designing Demand	James Heal, Naylor Industries (Yorkshire Flowepots), Owlston Nanotech, Navatas, Sugru,
Queens’ Award for Enterprise	Ancon Building Products, Aspen Pumps, Aurox, Centek, Hadley Industries, Heat Trace, Irisys, Limbs & Things, Linn Products, Milmega, NanoSight, Russell IPM, SELEX Galileo, Harrison Spinks, Stage One, Stanhope Seta, Survitec Group, Tangle Teezer, Tenmat, Track Analysis Systems, Zeeko
EEF Manufacturer of the Year Award	Xtrac, Pryor Marking Technology, Rayovac (MicroPower Division)

The companies demonstrate a common theme with their product ranges. The products variously (i) solve specific problems identified either by the users or by the company's research (or epiphany of the founders/directors), (ii) meet users' requirements, (iii) have desirable qualities and/or aesthetics, and (iv) are timely in the market. Similar qualities were identified in the literature review (Chapter 2). The influences of design in producing these successful products and in NPD were fairly apparent with companies expressing the importance of 'good design' in their promotional literature, especially for consumer products. In comparison, industrial products emphasised 'engineering' or 'functions' much more, and used the term 'design specific' for its technical ability to translate the idea into production, often used as a synonym or part of engineering. Furthermore, different perspectives (i.e. award types) provided evidence of the scope of design's contribution to the success of the products. Design-oriented awards demonstrated design's ability to understand the user and market demand, whereas the innovation award-winners tended to demonstrate a product's functional and technical abilities, with emphasis on efficiency and cost-savings to their customers. This is expected as the award itself acts as a amplifier of specific capabilities of design/innovation.

However, manufacturing companies demonstrated a lack of 'service' innovation. All awards recognise service innovations, but the research found difficulty identifying a manufacturing company which was also a service innovation winner. Although the emphasis of service from companies in the services or retail industry will be greater, as it is an integral part of their profit model, however, with the current surge of interest in services in the manufacturing sector it is not clearly delineated in either the manufacturing companies' awards or promotional materials.

5.3.2 Cases of design strategy for process innovation

Design as a catalyst to provide better processes in an NPD, production and designing in order to enhance process innovation, is demonstrated with the companies listed in Table 5.3. The strategy level of a business determines how a company utilises design professionals' capabilities as a user/market representative, mediator of collaboration, and holistic (system) thinker. The cases provide insight of how design strategy increases process innovation by (i) collaborating with external organisations (e.g. Thrislington

Cubicles, Touchline Flags, and Owlstone Nanotech, etc.), (ii) streamlining the production and NPD process (lean manufacturing) e.g. by utilising automation and CAD (e.g. Gripple, Naylor Industries, Owlstone Nanotech, Centek, Unilever, and Hadley Industries), (iii) provides a holistic overview of the process from concept to point of sale (e.g. Bolin Webb, KANO Computer Kit, Reckitt Benckiser, Limb & Things, Tangle Teezer etc.), and (iv) allocation of creative/collaborative space for employees (e.g. Specialist Precast Products and GSK Consumer Healthcare-Environment). It is important to note, however, that design acts as an agent to achieve these tasks rather than as a sole advocate. Internal collaboration is therefore a key to improving a process innovation through design strategy.

Table 5.3: List of companies demonstrating the presence of the 'design strategy for process innovation' area of design innovation spectrum

Origin of the Case	Manufacturing Companies
DME Award	Nightingale Care Beds, Thrislington Cubicles, Bolin Webb, Specialist Precast Products
dba Effectiveness Award	KANO Computer Kit, Touchline Flags, BT (Hub), BT (Phone), GSK Consumer Healthcare-Environment, TTI (AEG Powertools), Reckitt Benckiser (Lysol/Dettol), ICI Paints (Dulux Perfect Finish), Unilever (Project Rainbow)
Design Council Designing Demand	Gripple, Naylor Industries, Owlstone Nanotech, Sugru
Queens' Award for Enterprise	Aspen Pumps, Aurox, Centek, Hadley Industries, Heat Trace, Irisys, Limbs & Things, Linn Products, Milmega, NanoSight, Russell IPM, SELEX Galileo, Harrison Spinks, Stage One, Stanhope Seta, Survitec Group, Tangle Teezer, Tenmat, Track Analysis Systems, Zeeko
EEF Manufacturer of the Year Award	Xtrac, Pryor Marking Technology

The benefits of utilising design as a strategic tool is apparent both from literatures and the case study, and is particularly evident with the design-oriented awards winners where business decisions to maximise the utilisation of design in a company yielded rewards in increased production efficiency, sales and subsequent market share, profit, and by attracting of new investment. These benefits improved companies' market competitiveness, exploitation of new markets (including overseas markets), and created an innovative culture with greater structured employee involvement. It is at this level of business where a 'design champion' or design manager is likely to operate, taking on the role of an advocate of design values within the company. In order for manufacturing companies to become design-led businesses, this area of the design innovation spectrum is critical because it is the area where balanced decision-making must occur between business-oriented decisions by top-level managements and the creative product/service decisions by the design practitioners in the company.

5.3.3 Cases of corporate-level design thinking for organisational innovation

The research found that corporate-level design thinking can be used to improve organisational innovation, including the business model, company culture, company vision and strategy by using the methods and philosophy of design which emphasise creativity and user-centred approaches. Furthermore, the extent of design involvement in the manufacturing companies in the case study relies heavily on the drive or support from top-level management. All companies listed in Table 5.4 demonstrate this quality: in order for design innovation to thrive throughout the companies, by showing their commitment through greater involvement in innovation projects, driving changes in the company, and investing in NPD. These commitments - demonstrated in the testimonials and success stories in winning the awards - may arguably be biased, as a top-level manager's point of view. It is also difficult to determine whether design thinking is used to manage changes in these companies. However, the examples clearly show that the leaders place importance on understanding the users and delivering the necessary products to meets their demands. Design thinking in management places the users at the heart of innovation, clearly demonstrating a major part of design thinking in practice. Furthermore, some companies demonstrated their ability to use business model changes to drive innovation e.g. Nightingale Care Beds started a bed-rental service for care homes, and ICI Paints used their brand power to introduce a new line of brushes.

Table 5.4: List of companies demonstrating the presence of the 'corporate-level design thinking for organisational innovation' area of design innovation spectrum

Origin of the Case	Manufacturing Companies
DME Award	Nightingale Care Beds, Thrislington Cubicles, Specialist Precast Products
dba Effectiveness Award	Touchline Flags, Lovair, GSK Consumer Healthcare-Environment, TTI (AEG Powertools), ICI Paints (Dulux Perfect Finish)
Design Council Designing Demand	Gripple, James Heal, Naylor Industries, Owlstone Nanotech, Navetas, Sugru
Queens' Award for Enterprise	Hadley Industries, Heat Trace, Irisys, Limbs & Things, Linn Products, SELEX Galileo, Stage One, Zeeko
EEF Manufacturer of the Year Award	Xtrac

Entrepreneurial companies are also likely to more enthusiastically implement changes for the company as they discover new business possibilities while setting up the business (e.g. Sugru and Irisys). Manufacturing companies not listed in the Table may also use corporate-level design thinking in their management practice, but these were not obvious compared to those listed in the table who showcased the leader's commitment to innovation explicitly throughout their promotional materials, websites, interviews and talks. Companies such as Gripple demonstrate the managing director's continuing commitment to improving innovativeness in all areas of design innovation e.g. the company runs a regular internal ideas competition to encourage idea-sharing and collaboration in the company and increase innovative culture.

Continued innovation is important for the company to stay competitive in a rapidly changing market. Unfortunately some companies included in this study have been liquidated or show very limited activities. While there may be several reasons for this, it is a reminder that recognition as an innovative manufacturing company does not necessarily guarantee continued success without top-level managers' commitment to adopt to the ever-changing market.

5.4 Chapter summary

The design innovation spectrum illustrating the areas of design and innovation in a business context has been contracted in this chapter. A case study of the innovative manufacturing companies was conducted to identify the practical implications of each area of the design innovation spectrum.

The design innovation spectrum includes the areas of 'designing for technological, product and service innovation', 'design strategy for process innovation', and 'corporate-level design thinking for organisational innovation'. Evaluation of the design innovation spectrum indicated general agreement of its comprehensiveness and the relationship between design and innovation. Although opinions varied on the extent of design influence within a business, the final design innovation spectrum was created to accommodate the potential issues. The final design innovation spectrum includes details of attributes using the Kipling method to provide an overview of the business context in the spectrum.

The case study outlined the implications of each area of the spectrum. For designing for technical, product and service innovation area it provided products which (i) solve specific problems identified either by the users or by the company's research (or the vision of the founders/directors), (ii) meet users' requirements, (iii) are desirable for their quality and/or aesthetics, and (iv) are timely in the market. The design strategy for process innovation provided improvements by (i) collaborating with external organisations, (ii) streamlining production and the NPD process (lean manufacturing), e.g. by utilising automation and CAD, (iii) providing a holistic overview of the process from concept to point of sale, and (iv) allocating creative/collaborative space for employees. Finally, corporate-level design thinking for the organisational innovation area emphasised the importance of support from top-level management.

Using this comprehensive overview of design innovation in the innovative manufacturing context, in Chapter 6, more detailed design innovation characteristics will be identified as the basis of the design innovation framework. The characteristics will include design actions, effects and subsequent benefit for innovative manufacturing companies as identified from literature reviews and in-depth expert interviews.

Chapter 6. Design Innovation Characteristics

6.1 Introduction

Chapter 5 explored the relationship between design and innovation in a business context under the umbrella of the design innovation spectrum. This chapter discusses details of the design innovation characteristics which form the design innovation spectrum (see Figure 6.1 for chapter overview), with particular reference to the interviews conducted with both design and manufacturing experts (see Table 6.1) and literature reviews to identify the design innovation actions, their effects and benefits in increasing innovativeness in manufacturing companies. The interviews were conducted using a semi-structured face-to-face method asking questions about the influence of design in innovation for UK manufacturing companies. The responses were then collated to create a comprehensive list of twenty design innovation characteristics derived from eighty-four design innovation actions.

Table 6.1: Brief index of design innovation and manufacturing expert interviewees

Interviewees		Organisation
Design Innovation	DE1, DE2, DE3, DE4, DE5	Design Consultancy
	DE6, DE7, DE8	Design Promotion and Support Organisation (NGO)
	DE9, DE10, DE11	Governmental Innovation Support Organisation
Manufacturing	ME1, ME2, ME3, ME4, ME5, ME6, ME7, ME8, ME9, ME10, ME11	UK Innovative manufacturing Business

Note: See Chapter 3 for detailed descriptions of the interviewees

The research indicates that among design practitioners' and design thinkers' most influential capabilities are empathy and holistic thinking, through which their creativity is manifested in identifying, understanding and problem-solving (Cooper and Press, 1995, Mozota, 2002, Nelson and Stolterman, 2012). These capabilities are used both in the NPD process to produce an artefact or service, and in almost all areas of manufacturing business (Brown, 2005, Sawhney and Prahalad, 2010, Best, 2011). They are also essential traits if a company aspires to become more innovative (Bruce and Bessant, 2002a, CEC, 2009). As explained in the previous chapter, design capabilities in different areas of the design spectrum can indeed influence all areas of innovation including improving processes, defining company goals and vision, creating better business models, and creating innovation culture within the business. This is demonstrated in the interviews with the design experts and in much of the literature identifying that empathy is an essential trait which ensures that design practitioners and design thinkers have a deep understanding of customers' and employees' requirements, whether the customers are the end-user (consumer, B2C) or other businesses (B2B). Another essential ability of design practitioners and design thinkers is their ability to see a problem holistically, also referred as 'system thinking' (Jenkins, 2008): the ability to identify both immediate area of improvements and fundamental changes which can provide longer-term improvements. Design practitioners and design thinkers are thus able to identify users' problems and needs and provide both short-term and long-term solutions.

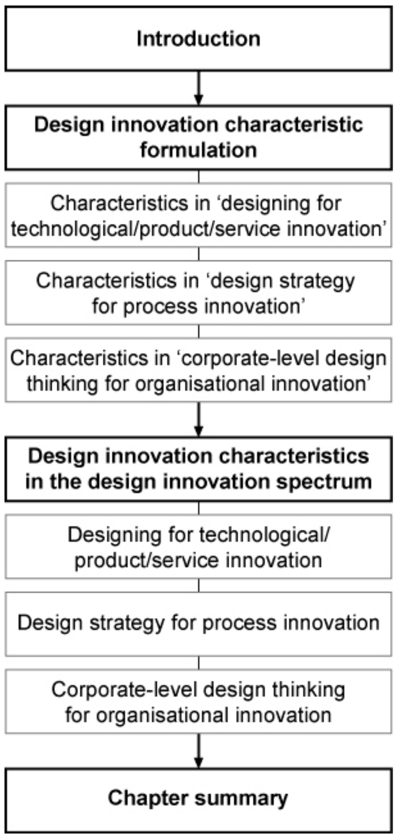


Figure 6.1: Chapter map

6.2 Design innovation characteristic formulation

Design practitioners' and design thinkers' capabilities are essential characteristics of design innovation, as derived from interviews with design and manufacturing experts, which were analysed using the system of coding (cycle of open, axial and selective coding) technique (explained in Chapter 3). The final cycle of coding process, the selective coding, created list of design innovation characteristics (see Table 6.2). The impact of each characteristic is identified by analysing the immediate changes derived from the research/data/action for each characteristic, loosely identifying whether the outcomes of those changes are mainly internal to the company e.g. the product development process, external to the company e.g. creating a product with appropriate functions for target users, or both (internal and external). It provides immediate recognition of the areas of influence of each characteristic, but such categorisation is inevitably prone to different perspectives. Further evaluation was thus conducted to ensure it was acceptable to the design and manufacturing experts (evaluation, see Chapter 7). It is also important to note that since most characteristics have interlinking relationships, as they share the same ultimate goal of improving innovativeness and enabling sustainable growth, overlapping design innovation actions are observed with different characteristics.

Table 6.2: Brief descriptions of design innovation characteristics

Design Innovation Spectrum	Design Innovation Characteristics	Place of immediate impact	Brief Descriptions
Designing for technological and product/service innovation	Technology Development/ Utilisation	Internal and external	Holistic scanning and capturing technological developments in and out of the company to be used in products/services
	Quality Improvement	Internal	Ensuring development of high quality products both technically (to help reduce failure and increase effective production) and visually (perception of high quality)
	Computer Aided Design (CAD)	Internal	Utilisation of CAD/CAM to enable effective visualisation and virtual prototyping leading to flexible manufacturing
	Technical Design	Internal and external	Optimisation of product functions and components for effective production and assembly (DFM/A)
	Aesthetics	Internal and external	Increasing desirability of products/services for emotional added-value for the customers
	Function/Usability	Internal and external	Ensuring appropriate functions and measures are embedded within products/services which are intuitive to use and easy to maintain

	Product/Service Value Promotion	Internal and external	Effective communication of the value of products/services to customers, potential customers and employees
	Graphics/Website	Internal and external	Utilisation of creative graphics on (including UI) and around (packaging and promotional materials, websites) the product/services
	User Need/Demand	Internal and external	Understanding of and empathy towards customers to identify their needs and demands for existing and potential new products/services
	Market Need/Demand	External	Holistic scanning of the current market to identify needs and demands, and scouting for potential new markets to exploit (including exports)
Design strategy for process innovation	Feasibility Testing (Prototyping)	Internal and external	Early and frequent prototyping to test feasibility for both form and function and for manufacturability of products/services to minimise risk of failure
	Knowledge Capture/Transfer (KM)	Internal	Ensuring appropriate tacit knowledge (employees' experience) are captured (often digitally) and transferred on demand
	External Collaboration (customer co-creation)	External	Collaboration with customers, suppliers and external agencies to assist product/service development (co-creation) and allow customisation both on product and process (open innovation)
	Internal Collaboration (Cross-positional, Interdepartmental)	Internal	Breaking down hierarchical barriers in a company by increasing effective internal communication, and encouraging collaboration between departments to share insights to enable cross-pollination
	Physical Work Environment	Internal	Creating a physical work environment which is exciting to work in and encourages collaboration
Corporate-level design thinking for organisational innovation	Top-level Management Support	Internal	Appreciation of the importance of design innovation by top-level management with design innovation champions in a company to encourage company-wide design adaptation
	Investments	Internal and external	Holistic analysis of the areas requiring more resources in order to enable innovation culture and invest or help secure external investments
	Company Vision/Values	Internal and external	Creation of a company's shared vision and values to enable effective communication with employees and encourage employee ownership and dedication
	Unique Selling Proposition (USP)	Internal and external	Identification or creation of the USP of products/services and the company itself to differentiate them in the competitive market
	Business Model	Internal and external	Evaluation of current sales channels and overall business practices to identify improvements or to create more effective channels to maximise profit and customer reach.

Each characteristic consists of design innovation (i) action, (ii) effects and (iii) benefits. The actions comprise design innovation activities, as identified by the expert interviewees. These include activities for all areas of design innovation, as identified in the design innovation spectrum (see Chapter 5). The effects of design innovation include both the tangible (e.g. increase production efficiency) and the intangible (e.g. increase employee engagement) outcomes of the actions. Combining these effects creates impact on manufacturing companies. In this research, the impacts are labelled ‘benefits of design innovation’.

6.2.1 Characteristics in ‘designing for technological/product/service innovation’ area

In this section, the design innovation characteristics are identified to be mainly within the boundary of ‘designing for technological/product/service innovation’ area within the design innovation spectrum including: (i) technology development/utilisation, (ii) quality improvement, (iii) Computer Aided Design (CAD), (iv) technical design, (v) aesthetics, (vi) function/usability, (vii) product/service value promotion, (ix) graphics/website, (x) user need/demand, and (xi) market need/demand (Table 6.3). Design innovation characteristics placement within the design innovation spectrum is further discussed in Section 6.3.

Table 6.3: Design innovation characteristics within the ‘designing for technological and product/service innovation’ area of the design innovation spectrum

Design Innovation Spectrum	Design Innovation Characteristics	Place of immediate change (impact)
Designing for technological and product/service innovation	Technology development/utilisation	Internal and external
	Quality improvement	Internal
	Computer Aided Design (CAD)	Internal
	Technical design	Internal and external
	Aesthetics	Internal and external
	Function/Usability	Internal and external
	Product/Service value promotion	Internal and external
	Graphics/Website	Internal and external
	User needs/demands	Internal and external
	Market needs/demands	External

6.2.1.1 Technology development/utilisation

In the first generation of innovation process (Rothwell, 1994), ‘technology push’ was the major innovation initiative in the 1950s and mid-60s. The technology-based innovation process has become more complex over the years with overlapping considerations, including R&D, innovation decision, marketing, manufacturing and capital capabilities (Wang et al., 2008). Utilisation of technology is supported by the UK government through Technology and Innovation Centres across the UK to deliver new/improved products and processes (TSB, 2011b). The development of new technologies through scientific discoveries and/or R&D can be an enabler for better products, manufacturing processes and services. In this environment, the research has found three major design functions: (i) commercialisation of new technologies into the market, (ii) use of appropriate technologies to provide an optimised solution for an immediate problem, and (iii) identification of needs to engage specified technology development.

The majority of the design experts identified the importance of design in effective technology utilisation. In order for a company to have design innovation characteristics, the research identified design innovation actions in technology scouting (interviewees DE1, DE2, DE4, DE5, DE6, DE8 and DE10), technology adoption (interviewees DE1, DE2, DE3, DE4, DE8 and DE11), and initiation of technology development (interviewees DE2, DE3, DE4, DE9, DE10 and DE11). Technology scouting is the ability of designers to look for wider areas of technologies by "thinking outside the box" (interviewee DE1) in order to solve a problem, and technology adoption is applying technologies developed internally or externally to create and/or improve products which are appropriate for the market and the users. For example, interviewee DE2 mentioned a bio-experimental equipment project led by his consultancy, where the application of new technology, originally developed for other applications, resulted in creating a range of products which were easier to use and more efficient. Furthermore, input from designers to understand both market and customers can reduce the risk of R&D failure by providing a market-appropriate R&D direction (interviewee DE3). These actions are not limited to technologies used in a product or service, but also include technologies in the production process e.g. interviewee ME3 mentioned a designer's critical input to using new injection moulding technology in the manufacturing process to provide a better quality consumer product.

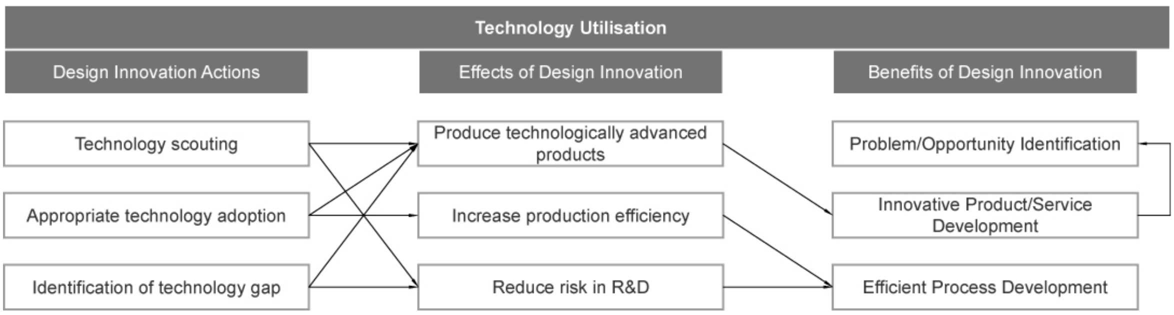


Figure 6.2: Details of design innovation characteristics for technology development and utilisation

The importance of technology utilisation characteristics is further emphasised by the UK government's manufacturing support organisation which provides design mentoring for businesses wishing to apply for a grant for commercialisation of technologies (interviewee DE10). Thus, as illustrated in Figure 6.2, the primary effects of the design innovation characteristics in technology utilisation are in innovative product/service development and effective process development. Further influences include problem/opportunity identification derived from the innovative product/service development, where the iterative process of scouting and adopting technology can help discover new problems and opportunities for products and services under development.

6.2.1.2 Quality improvement

The research found that one of the most important aspects of a product or service is quality, according to many manufacturing experts (interviewees ME2, ME5, ME6, ME8, and ME9). Bentley (1999:1) uses the British Standard (BS 5750) to define quality as "the totality of features and characteristics of a product, process or service that bear on its ability to satisfy stated or implied needs". Hoyle (2007) also concurs with the manufacturing experts by stating that quality is one of three fundamental criteria determining the saleability of products or services, together with price and delivery. An international standard (ISO 9000 series) has been used to assess a company's ability to provide quality in their practices, and is often used by manufacturing companies to showcase their commitment to quality. The ISO 9000 series defines quality similarly to Total Quality Management (TQM), which includes expansive elements of business which contribute to better quality practices and outcomes. However, the term 'quality' has more focused meaning when referring to the characteristics in this section, which is directly related to products/services.

Quality can be determined by many factors: design management and product design performance both play a significant role (Ahire and Dreyfus, 2000), which is echoed by both manufacturing and design experts, suggesting that design has characteristics which provide consistently high quality products and services. Firstly, the product or service design can be developed in accordance with the required level of quality. Design practitioners help identify customer expectations by understanding their underlying issues through design research methods, including observation (interviewees DE1 and DE2), often exceeding these expectations to provide greater perception of quality to the users (interviewee DE4). The information gathered is then used to develop a product or service, usually with the simplest components to reduce the number of breakdowns and provide consistent quality throughout the life of the product. The role of engineering design is emphasised in this task, where components and assembly structures are designed for minimum risk of failure during operation. Most of the manufacturing experts discussed this vital role of design (interviewees ME2, ME3, ME5, ME6, ME7, and ME9) which can be achieved by simplifying the components used, and choosing appropriate materials and production methods. These methods are also discussed by Boothroyd et al (2002), noting that appropriate use of design for manufacturing and assembly (DFM/A) can also benefit by reducing the cost of manufacturing and assembly. Furthermore, interviewees ME10, ME11, DE1 and DE2 discussed a design innovation action which creates products with easy access to service (serviceability) in the later stage of its life if a failure occurs. This helps both users and service technicians to easily fix the problem and maintain the quality of the product.

Aesthetically, design can also assist by providing the perception of a high quality product - the third biggest impact of design (Mozota, 2002). This is also apparent when users have difficulty in directly assessing the quality (Berkowitz, 1987). Interviewee ME5's company produces filters for the oil industry which are only visible when it is being placed in the pipe and are then hidden from view until the end of their life. However, they use high-quality tactile materials with beautiful packaging to manifest the product's quality to the client company's technicians. Such attention to detail gives the impression of high quality among other competitors offering cheaper alternatives. In order to achieve the perception of quality, interviewee ME5 and design experts interviewees DE2, DE5 and DE11 all stressed the importance of consistency.

The research identified the effects of quality improvement characteristics by design innovation (see Figure 6.3), including reduction in defects and failures and increased service efficiency, quality appearance, and desirability. All these effects are related to innovative product/service development, where quality is a deciding factor in commercial success. Furthermore, by developing innovative products/services, the process of quality management (TQM) and quality assurance (QA) processes are likely to become more effective in managing the quality of products/services.

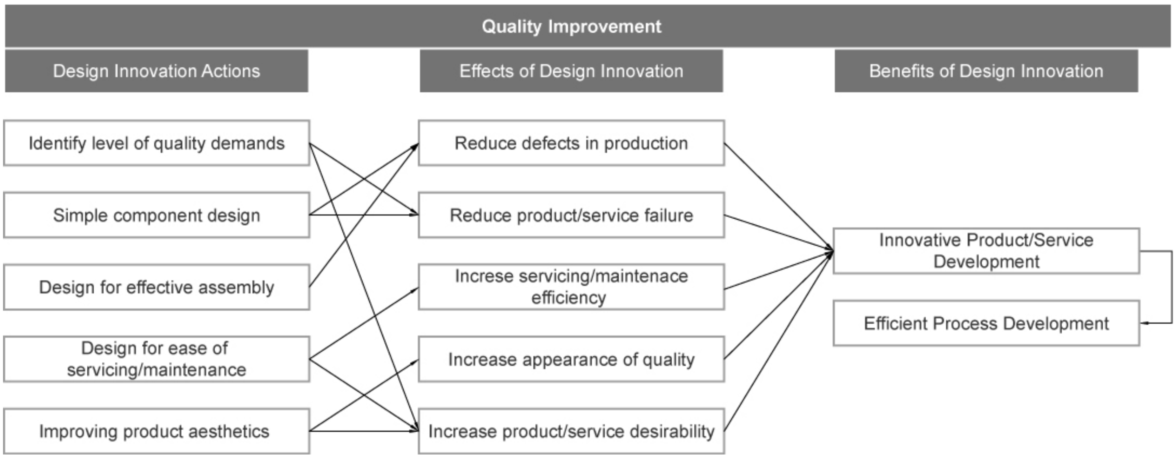


Figure 6.3: Details of design innovation characteristics for quality improvements

6.2.1.3 Computer Aided Design (CAD)

Automation by using CAD and computer aided manufacturing (CAM) is an important element in optimising manufacturing process and enabling flexible manufacturing. As the name suggests, CAD is the process which creates virtual three-dimensional models and two-dimensional drawings of products (Bryden, 2014). Interviewee DE2 suggests that recently reduced CAD software costs have “made an astonishing difference” in expanding its usage by design practitioners to reduce the design delivery time from conceptual design to design for production by digitising ideas, while improving visualisation (interviewees DE2 and DE5). Similarly, Best (2006) argues that visualisation is among a design team’s key abilities and CAD renderings help achieve this more effectively. However, as Pugh (1996) points out, CAD in manufacturing companies is often used only in the later stages of product developments by the engineers. It is used as a virtual prototyping tool to simulate material property testing, raw material waste calculation, assembly processes etc., to ensure optimum choices can be made (interviewee ME1). Furthermore, manufacturing companies have utilised the capability of CAD and subsequent CAM in the production process to increase product accuracy by using CNC machines (interviewees ME5 and ME9). The advantage of using CAD is being recognised by manufacturers with continuing investment in both software and subsequent training (interviewee ME2). Boer and During (2000) found that most successful flexible manufacturing systems (FMS) practitioners are likely to have experience of implementing CAD/CAM systems. Interviewees ME5 and ME9 concurred with this when discussing the use of CAD/CAM to increase flexibility in both the 'designing' and 'production' stages of manufacturing. Furthermore, with increased interest in 3D printing technology, the importance of CAD capabilities is becoming more apparent in manufacturing (interviewee ME6).

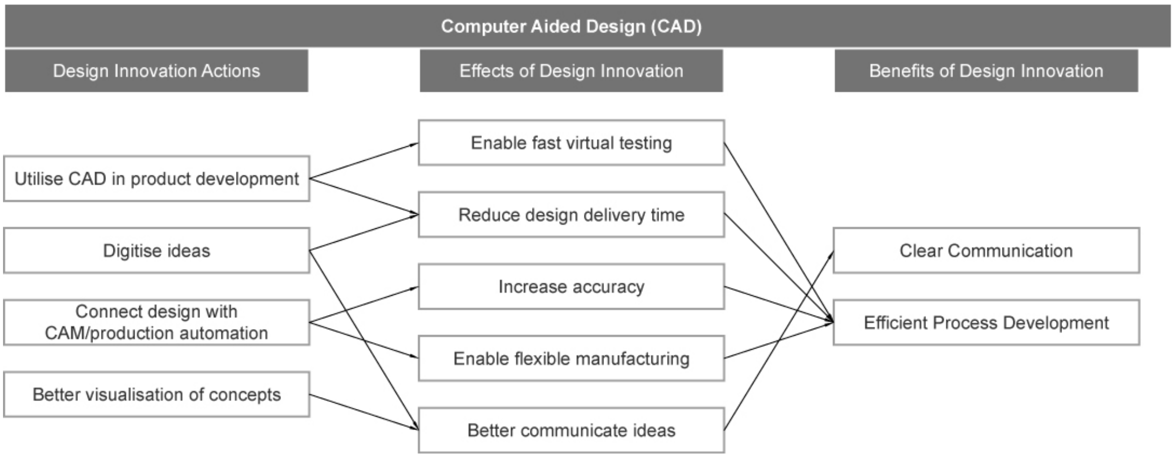


Figure 6.4: Details of design innovation characteristics for CAD

The research found that CAD as a design innovation characteristic enhances communication of ideas, concepts and final designs (see Figure 6.4). It also contributes toward creating efficient processes with greater accuracy and shorter design delivery time and helps enable flexible manufacturing through quickly changing specifications according to the demands of the production process or of the clients.

6.2.1.4 Technical design

Technical design refers to the part of design which solves technical issues for product creation and production process (Livesey and Moultrie, 2009). It is also described as a 'technical ability' of design practitioners, such as the ability of using CAD software (ME5), visualising ideas (ME2), aesthetical improvements of products and promotional materials (ME8 and ME9). Therefore, the technical design has two sides: one is about solving problem for the product itself, and the other is design practitioners' technical ability to actually design a product. Both are closely related to DFM/A and engineering design, which aims to increase manufacturability of products and efficiency in product assembly, while also focusing on the functionality of a product (DE1, DE2, DE7, DE8, DE9).

Current understanding of design by innovative UK manufacturing companies is mostly of technical design (see Chapters 4 and 5), the area of design most heavily invested in by manufacturers, representing over 90 per cent of total design spending (Livesey and Moultrie, 2009). This was reflected in the interviews, almost all interviewees suggesting that technical design is one of the most apparent characteristics of design innovation recognised by the manufacturing companies. According to Boothroyd et al (2011), DFM/A implementation benefits include cost savings, ease of design, reduced development costs, streamlining the development cycle, improved project timelines, and a reduction in resources needed for a project. For example, in the manual assembly situation, designing parts which do not tangle or jam when stored in bulk, or providing chamfers to allow easy insertion. In order to achieve these, Balachandra and Friar (1997) suggest effective prototyping and concept evaluation, which concurs with interviewee ME6's view. Interviewees DE2 and DE5 also mentioned designing modular platforms which are shared across a product range to further increase efficiency and cost savings, help reduce waste in defects, inventory, processing, waiting, motion, transportation, and overproduction, the seven major areas Lean manufacturing must address – regarded as an important way to increase the company's efficiency and innovativeness (Moody, 2001).

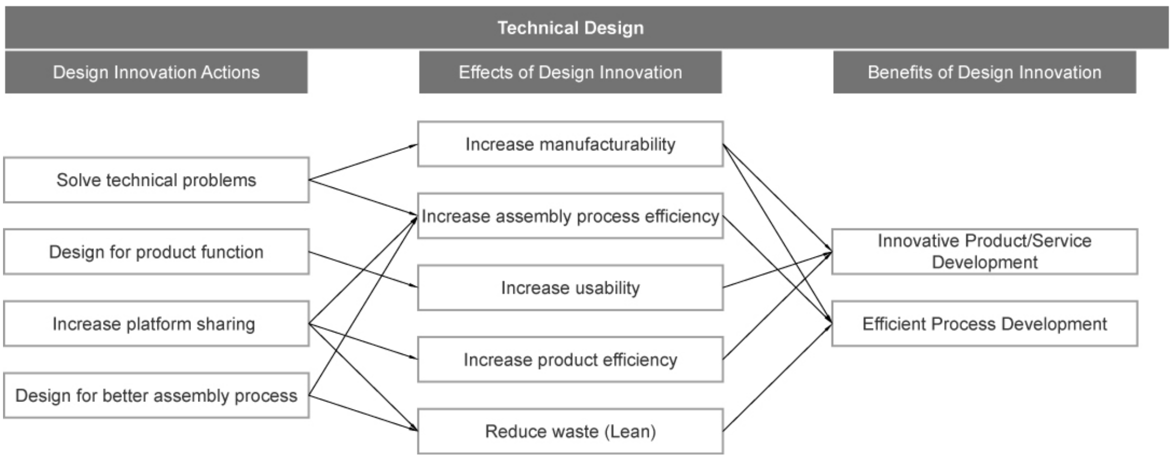


Figure 6.5: Details of design innovation characteristics for technical design

Technical design as a design innovation characteristic is the most recognised element of design where it forms a major part of design as a functional activity for manufacturing companies. It is closely linked with the technical terms CAD and 'function/usability' as it can be a source of those characteristics. The research demonstrates the actions taken by technical design in the NPD environment (see Figure 6.5). It is a critical element in developing innovative products/services and efficient production and assembly processes.

6.2.1.5 Aesthetics

All interviewees agreed that a product's pleasing aesthetics or appearance are among the most obvious benefits of design. A product's aesthetic appeal is determined by shape, colour, size and material used (Poli, 2001). However, the nature of manufacturing can dramatically change the emphasis of aesthetics. Customer facing manufacturing companies (B2C) are more likely to place aesthetics higher up the agenda and use it as a design innovation strategy (Berkowitz, 1987) than that of B2B or Tier 1 Manufacturing companies where they are less inclined to put aesthetics at the same level as functionality (interviewees DE6, DE7 and DE10). Some B2B or Tier 1 manufacturing companies may be more concerned about the appearance of publicity materials (brochures, exhibition poster and stands etc.,) as far as the aesthetics are concerned. Interviewee ME9 commented candidly about use of design, saying, "we give all the information [for a brochure] and they [the external design agency] make it look nice." This is certainly a part of designing for aesthetics, but Yamamoto and Lambert (1994: 309) state that "More than simply the creation of pleasing product shapes and styles, the industrial design role in product development can be viewed as a communicator of the firm's quality image and product integrity." Interviewees ME5, ME6, ME8 and almost all design experts agreed with this statement and explained that the aesthetic adds emotional value to the products and subsequently has a positive effect on the brand itself. In order to achieve this, consistent cues in aesthetics across the range of products and communications materials are important to convey the desired brand message which also influences improved publicity materials (interviewees DE2, DE5 and DE11). The aesthetics characteristic of design innovation can also be used as a fashion statement for a product to increase desirability where trends in colour, shape and materials are appropriately applied to create added value for the product (interviewees DE1 and DE5). Aesthetics can also be heavily determined by a product's specific function. Interviewee DE5 discussed the distinct shape of the Japanese Shinkansen (the 'bullet train'), which is designed to decrease drag coefficient to maximise functionality rather than to create- a typical example of form following function.

The research found that aesthetics as a design innovation characteristic act to communicate quality, convey brand message, leading trends which can also be determined by a product's function - actions which result in clearer communication and help develop innovative products/services through increased desirability, adding product brand values, enhancing communication and the function of products/services (see Figure 6.6).

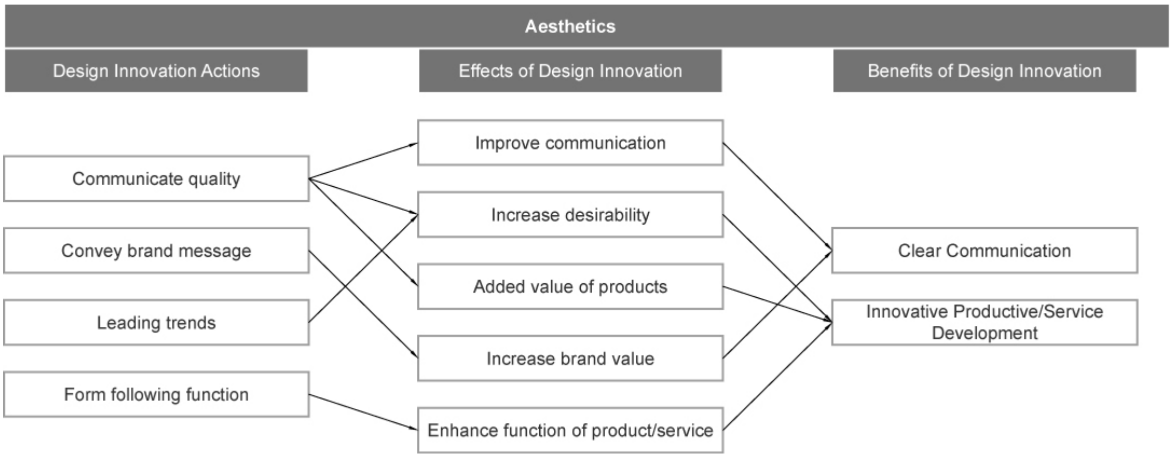


Figure 6.6: Details of design innovation characteristics for aesthetics

6.2.1.6 Function/Usability

Function and usability are among the most fundamental values of a product or service. Their successful acceptance in the market heavily depend on a deep understanding of both market and users, identifying the optimum level of functional features with intuitive user experiences (interviewees DE1, DE3, DE4 and DE11). For B2B manufacturing companies, the users include their clients. The innovative manufacturing companies studied in this research identified the importance of understanding their clients' needs, especially when providing bespoke products/services. This is commonly identified as competitive advantage against overseas manufacturers who are likely to have a slower response to clients' changing demands (interviewees ME2, ME4, ME5 and ME11). Providing a bespoke product, part of flexible manufacturing, requires continued dialogue between manufacturer and clients. In a design process, this collaboration is optimised to provide accurate solutions which meet client requirements (interviewee DE9). Furthermore, design as a creative agent can be used to help identify the required functions for products/services by holistically reviewing the needs of the users or systems using the product (interviewee

DE1). Design research - including the customer journey, target audience preferences and ergonomic requirements (interviewees DE1, DE2, DE5 and DE11) - all contribute towards designing products/services which provide appropriate functions and intuitive usability to increase user experience and satisfaction (interviewees ME3, DE1, DE2 and DE8).

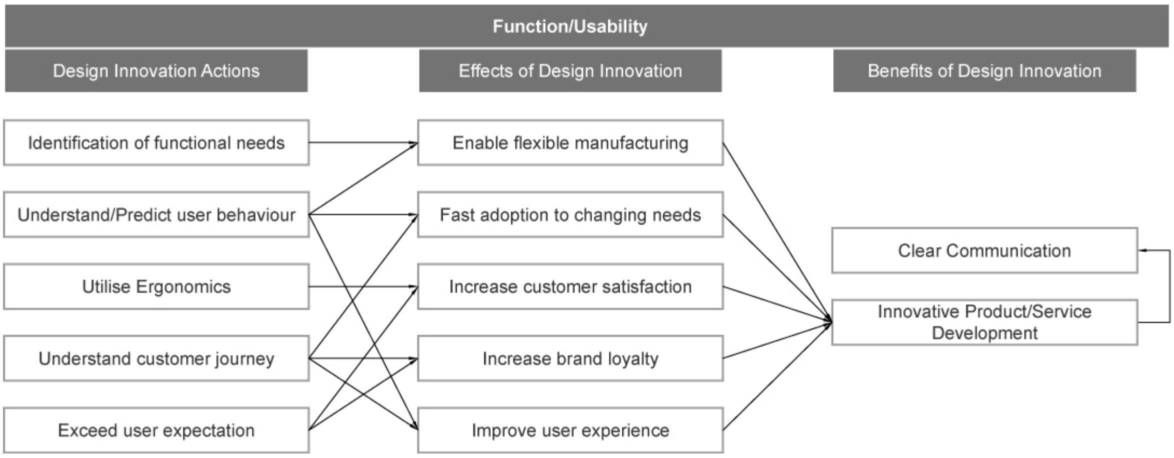


Figure 6.7: Details of design innovation characteristics for function/usability

Manufacturing experts, especially from B2B oriented manufacturing companies, focus on the products' functions and place emphasis on meeting specifications on time and on budget. At the same time, the design experts provided insight into how to identify and exceed the users' expectations whilst using a product/service. In order to develop innovative products/services, both viewpoints are important because they address the core product/service value to the customers (see Figure 6.7). However, 'appropriateness' of both function and usability is considered with caution because it is easy to over-engineer or include unnecessary functions in a product (ME6). Successful execution of design innovation actions in the NPD process can enable greater understanding of the functions and usability of products/services, with the secondary benefit of providing clear communication internally (with employees) and externally (with users).

6.2.1.7 Product/Service value promotion

Value, according to Sweeny and Soutar (2001), comprises quality, emotional, price and social dimensions, the milestones manufacturing companies attempt to deliver to their customers through their products/services. In the previous sections, the research addressed how well-designed products/services with desirable aesthetics, appropriate functionalities and intuitive usability can increase the perception of a product or brand’s quality. However, it can be difficult in the globalised market to promote product/service value to target audiences where there is likely to be a competitor selling similar products/services (interviewee ME10). Manufacturing companies use design to make a brochure “look good” (interviewee ME9). Another manufacturing expert (interviewee ME8) mentioned that a well-designed booth in a trade-show, denoting quality, attracts more buyers. This aspect of design provides visual communication intended to increase understanding of the product/service values. However, design can also help manufacturing companies to understand the target audience better, with a wider commercial perspectives (DC, 2012b), to promote the emotional and social dimensions of product/service values (interviewee DE1 and DE5). Moreover, design practitioners equipped with this user information can identify effective and creative promotion methods by embracing various possibilities including using both digital and printed medias as well as utilising the packaging to promote the value of the product/service and the brand itself (interviewees DE1, DE6, DE7 and DE8). Moreover, these design innovation actions can also be used internally, where clearly promoting product value can help increase employee pride (interviewee DE6).

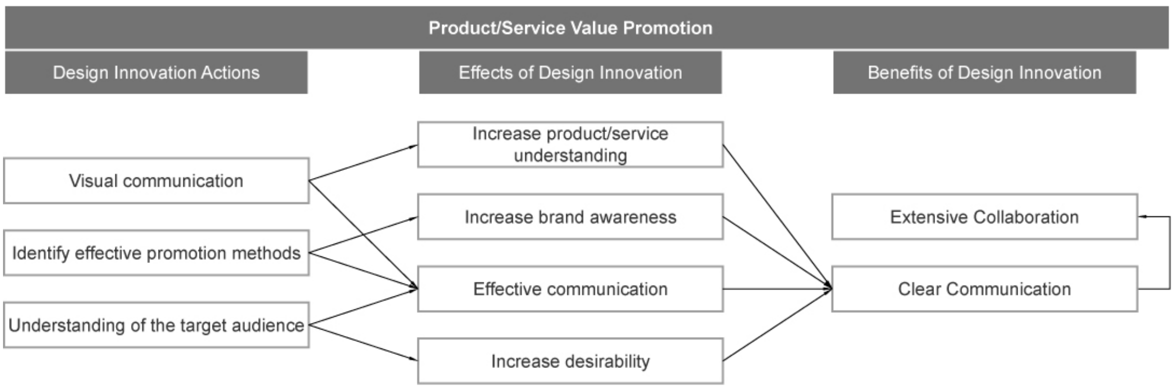


Figure 6.8: Details of design innovation characteristics for product/service value promotion

Promoting product/service value can be seen as a straightforward design task, according to some manufacturing experts. However, their ability to enhance understanding of products/services and subsequently the brand should not be overlooked. This design innovation characteristic also provides effect communication and increased desirability (see Figure 6.8). The benefit of product/service value promotion as a characteristic of design innovation thus engenders clear communication, which in turn can have secondary influences on collaboration by enhancing stakeholders' understanding of the value of the products/services.

6.2.1.8 Graphics/Website

Manufacturing companies also recognise graphics as a form of design, albeit with very limited functions such as creating promotional materials and websites (interviewees ME7 and ME9). Manufacturing companies, usually SME companies without graphic design professionals, usually contract out this work to an external agency in conjunction with marketing. However, graphics has greater implications in creating products/services which are engaging to use, and enhance the company's branding (interviewees DE1, DE6 and DE7). Furthermore, intuitive control graphics on a user interface can increase the ease of use (interviewee DE1). Its importance was identified by several design experts (interviewees DE1, DE2, DE5, DE6 and DE10) because preliminary customer engagement occurs amongst the various touch-points of products/services, whether on a shelf, in a catalogue or on a website. Skilfully executed graphics also communicate information clearly and effectively both internally and externally. The internal communication (branding) is important in creating shared understanding of the company and thus a better work culture. A visual representation of the business vision and strategy can simplify, clarify and alleviate confusion on a topic which can be hard to comprehend (Phaal and Muller, 2009). It can also promote a company's emotional values to maximise employee attachment to the brand, leading to increased loyalty and ownership (interviewee DE11). Similar qualities also apply to the external use of graphics. Intrinsic to the aesthetics of a product/service, it provides added branding value easily recognisable by customers (interviewees DE1 and DE6). Furthermore, by clearly demonstrating values of yet-to-be launched products/services it creates a sense of anticipation, which can help win contracts and further investments (interviewees DE6 and DE7). An intuitive graphic interface with simple and clear instructions for products/services also increases perceived quality and can therefore be a competitive advantage (interviewees ME5, ME7, ME9, DE1, DE3, DE5 and DE6). The clarity of instruction is also closely linked with the usability and serviceability of the product/service (interviewee DE1).

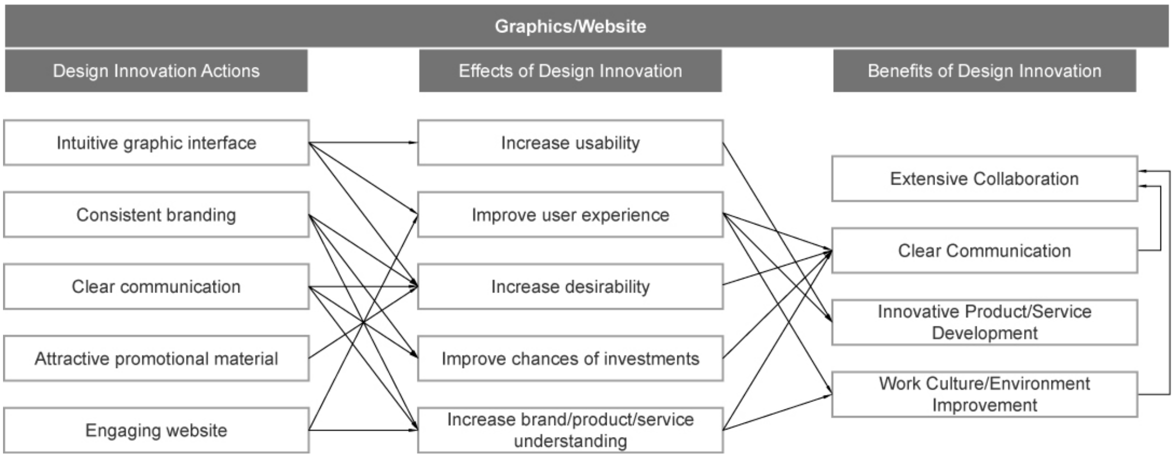


Figure 6.9: Details of design innovation characteristics for graphics/website

The effects of graphics as a design innovation characteristic can be observed in various areas of manufacturing companies. The research has identified the three major effects of graphics. Firstly, it is used as a means to visually and effectively communicate messages, both internally and externally, as an aid to better branding. Secondly, it is embedded in a user interface to increase usability and user experience. Thirdly, using trendy graphics on a product, packaging, promotional materials and/or websites, can attract further customers and increase the desirability of the product/service. Therefore the graphic/website characteristic provides the benefits of creating clear communication, developing innovative products/services and improving the work culture/environment (see Figure 6.9). The improved understanding of brand, product and service through clear communication and subsequent work culture/environment improvement also provides secondary benefits for improving collaboration both internally and externally by ensuring mutual understanding between the stakeholders.

6.2.1.9 User needs/demands

Design practitioners' research tools include interviews, focus groups, workshops, customer journey mapping and observation etc., to understand the users (Kumar, 2013). These methods are usually planned and initiated by design practitioners (or design managers) within or external to manufacturing companies in conjunction with marketing (interviewees DE1, DE2, DE3, DE5 and DE8). The users concerned in this section include both internal (employees) and external (consumers, client companies) people who engage with and buy-into the outcome of the design, whether artefacts, services and/or processes.

Discussion with both manufacturing and design experts has been predominantly about the external users. However, inclusion of internal people as users was suggested by design experts who believed the extensive influences of design also expand to creatively cater for the needs and demands of internal staff to create an exciting environment they are proud to work for (interviewees DE3, DE6, DE7 and DE8).

The importance of design to understanding the users' needs and demands to achieve successful innovation is emphasised ubiquitously in much research. A recent Design Council study of design investment by business leaders (DC, 2014) emphasises this characteristic of design innovation as a route to radical innovation. Empathy is a key design quality which can provide insight into users and their surroundings (Cooper and Evans, 2006). Predictably, all the design experts commented that understanding and empathising with users' needs and demands is decisive factor that determines the success or failure of products/services. The manufacturing experts also concurred on the importance of understanding user/client demand. However, they also mentioned that the nature of a business can limit the willingness of user understanding e.g. B2B companies, especially the suppliers (Tier 1 or Tier 2 onward), are less conscious of the final users' needs and are likely to produce products/services only conforming to their clients' specifications (ME6, ME8). This is 'passive user understanding' in comparison with a more 'proactive user understanding' mentioned by all the design experts and some manufacturing experts (ME3, ME4, ME9) which adds value to products/services by forecasting future user demand through a deeper, more comprehensive understanding of user demands and behaviours. Interviewee DE4 emphasised this, using the term 'standards' and 'extras' where "there is an expectation to deliver standard... adding the extras to it [partly through design] is delighting the consumer". Importantly, this can contribute towards prioritising user need/demand and formulating a company's strategic direction to deliver added value to its customers, thereby increasing its competitiveness.

The benefits gained from user need/demand characteristic of design innovation (Figure 6.10) are: (i) problem/opportunity identification, where understanding the users' requirements is fundamental to developing a product/service, (ii) clear communication, whereby user insights are effectively distributed across a company, and (iii) innovative product/service development as user understanding and prioritised user need/demand can be effectively used to create a product which exceeds expectations. Furthermore, when applied internally, employees' needs/demands can be understood much more clearly. It therefore has secondary benefit in creating a better work culture/environment.

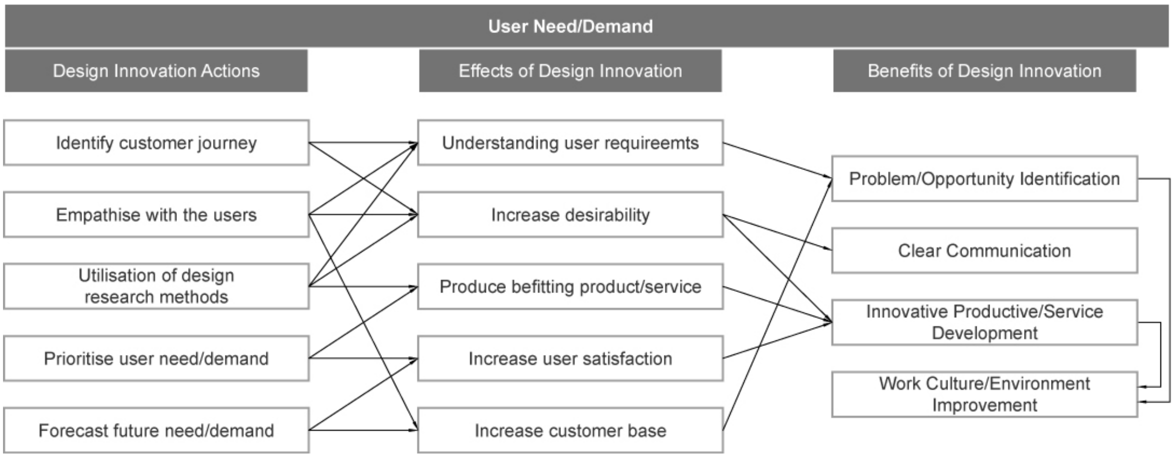


Figure 6.10: Details of design innovation characteristics for user need/demand

6.2.1.10 Market needs/demands

To be successful in a market, a company must be in tune with market needs and demands, or there is a chance of market rejection of the product or service, even with advanced technology, because of being 'ahead of its time' (Sawhney and Prahalad, 2010). A company can deliver successful products/services for a market in two ways. One is 'market pull'- as described by Rothwell (1994) - where a market need is identified and products/services development responds to take advantage of the opportunity by addressing that need in the appropriate timeframe. Another approach is exploring or creating a new markets with a company's existing technologies or competencies to increase sales and market share (interviewee DE8), similar to the 'technology push' also described by Rothwell (1994), the route often taken by research-based technology start-up companies. The advantage of the former approach is that the company can reduce risks in launching a new product/service, whereas the second approach can reduce the cost and time in technology or new product development in launching products/services in a market (interviewees ME6, DE2 and DE9). Both approaches require a company's deep understanding of changes in their current market segment and a holistic view of other markets they could exploit (Mosey, 2005), and a good knowledge of the company's competence and limitations in existing and/or new markets. Almost all interviewees recognised the direct link between appropriate market understanding and the success of product/services. However, the design experts (interviewees DE2, DE3 and DE10) emphasised the contribution of creative and holistic design approaches to provide a deeper understanding of the market

The research indicates that design innovation actively scouts for market opportunities, whether developing new products or introducing existing products or services to a new market (interviewees DE5 and DE6). This holistic approach to understanding the market offers unexpected opportunities and areas of exploitation which can lead to increased presence in the markets. Furthermore, current market competitors can also be better understood by using design-led tools (interviewees DE1 and DE2) such as the 'competitors-complementors map' and strategic business tools e.g. 'SWOT' (Kumar, 2013). Prioritising possible product or service developments and/or improvements is vital to increasing the chance of successful exploitation and staying competitive in the market (interviewees DE4, DE6 and DE8) which requires collaborations internally and also with external experts and organisations. This is also relevant for reacting promptly to market changes where the companies are able to adapt quickly to new market demands and needs (interviewees ME2 and DE8) to capture and retain market share, and increase profitability (Tidd et al., 2005).

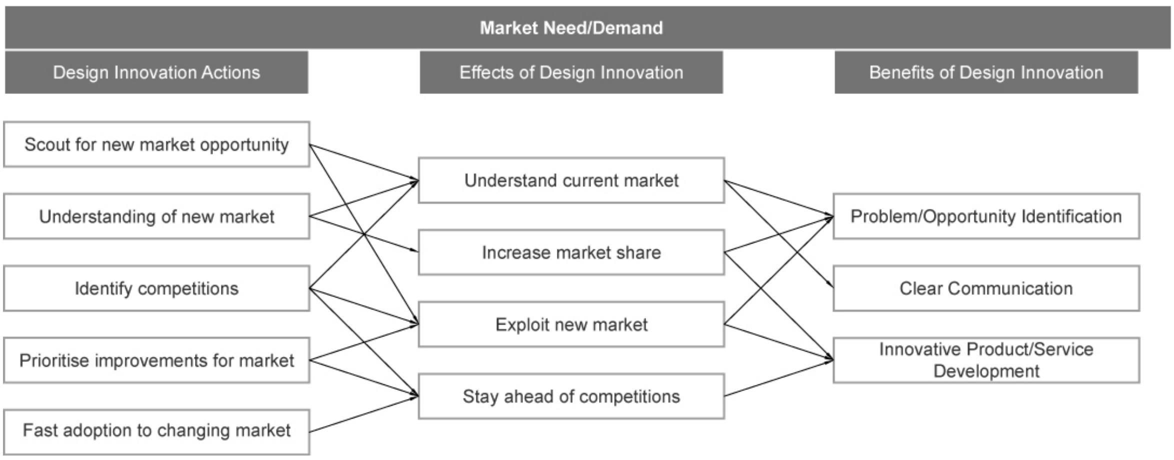


Figure 6.11: Details of design innovation characteristics for market need/demand

The market need/demand characteristic of design innovation provides holistic, yet detailed understanding of the context of the market in which products/services are being used. Through this design research, both problems and opportunities can be identified, clearly communicating the priorities to meet the market needs/demands to the management of a company. Furthermore, the exploration of the new market through prioritising improvement on current product/service will be the basis of a design brief that will focus development of innovative product/service that is likely to be successful in the market (see Figure 6.11).

6.2.2 Characteristics in 'design strategy for process innovation' area

Design innovation characteristics identified in this section mainly have their action and effect within the area of 'designing for technological/product/service innovation' in the design innovation spectrum which shows the main actors and business level where main decisions are undertaken. The characteristics include: (i) feasibility testing (prototyping), (ii) knowledge capture/transfer (part of Knowledge Management-KM), (iii) external collaboration (customer co-creation), (iv) internal collaboration (cross-positional, interdepartmental), and (v) physical work environment (Table 6.4). Design innovation characteristics placement within the design innovation spectrum is further discussed in Section 6.3.

Table 6.4: Design innovation characteristics within the 'design strategy for process innovation' area of the design innovation spectrum

Design Innovation Spectrum	Design Innovation Characteristics	Place of immediate change (impact)
Design strategy for process innovation	Feasibility testing (prototyping)	Internal and external
	Knowledge capture/transfer (Knowledge Management-KM)	Internal
	External collaboration (customer co-creation)	External
	Internal collaboration (Cross-positional, Interdepartmental)	Internal
	Physical work environment	Internal

6.2.2.1 Feasibility testing (prototyping)

Feasibility testing using prototyping is an integral part of a design process which translates concepts or ideas into 2D or 3D forms. It aims to identify potential issues both in production and user adoption in the early stage of product development in order to identify possible flaws, reduce potential market failure points and increase consumer adoption

(Hallgrimsson, 2012). Most of the manufacturing and design experts acknowledged the importance of prototyping in various stages of NPD because it can help visualise the idea better (interviewees DE1, DE2 and DE8), test the manufacturability of the concept by using methods such as rapid prototyping (interviewee ME6), and identify user preferences by testing a working prototype with potential users for a product or service's function, ergonomics (usability) and aesthetics (interviewees ME9, ME11, DE1, DE2 and DE5). The research also identified that frequent prototyping generally has higher impact on product or service adoptability by reducing the risk of product or service failure (interviewees ME10, DE6 and DE8). However, because of budget and time constraints (including staff time and financial resources), it is not always possible to carry out the feasibility testing as often as desired (interviewee ME10). Furthermore, interviewee DE4 sceptically commented on user testing because sometimes their product or functional preferences in a test environment does not guarantee product purchase. The test result must therefore be analysed cautiously, to increase chances of success in a market.

The principle of prototyping is also implemented in the corporate design thinking process for business development where it is used to test a business concept in order to reduce business risks (Brown, 2008, Liedtka and Ogilvie, 2011). Early detection of problems is considered important in enhancing innovativeness (Bessant and Tidd, 2007, von Stamm, 2008) and prototyping provides this insight both quickly, by articulating ideas using crude prototypes, e.g. cardboard models and rapid prototyping, and thoroughly, by using working prototypes visually and functionally similar to the final product.

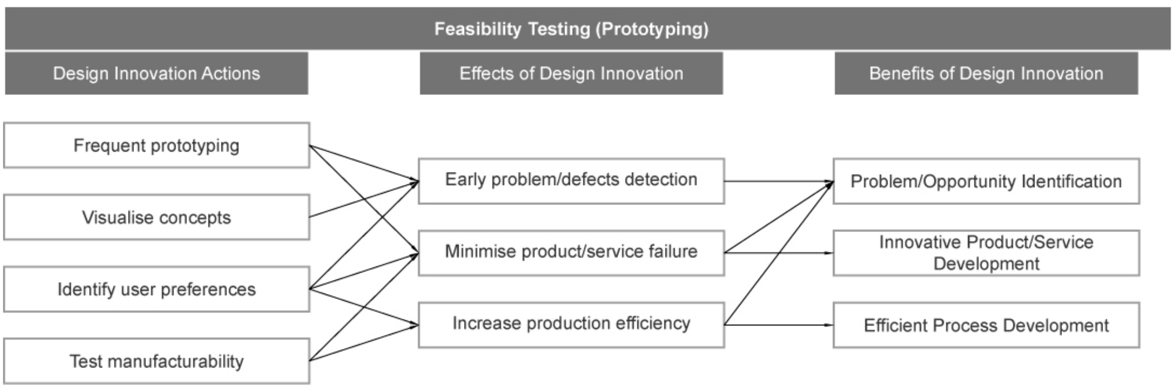


Figure 6.12: Details of design innovation characteristics for feasibility testing (prototyping)

Figure 6.12 describes the benefit of feasibility testing as a characteristic of design innovation which includes enabling more accurate problem/opportunity identification, innovative product/service development more relevant to the end-users, and efficient process development by early detection of potential production issues early in the development stage.

6.2.2.2 Knowledge capture/transfer (Knowledge Management- KM)

Knowledge is an important asset for any company to increases competitive advantage (Soosay and Hyland, 2008) and improves organisational performance (O'Dell and Grayson Jr., 1998), and is especially difficult to capture and utilise, especially when based on employees' (tacit) experience (Nonaka, 2007). Bertola and Teixeira (2003) describe three types of knowledge in which design, as a knowledge agent, supports the development of business innovation: 'users' community knowledge', 'organisational knowledge', and 'network knowledge'. In this section, organisational knowledge is considered because other types of knowledge are considered under different design innovation characteristics. Interviewees ME3, ME5 and ME7 (who all indicated the importance of knowledge transfer) concurred with the literature findings about the importance of knowledge. Interviewees ME5 and ME7 indicated that they use a computerised system to attempt to capture knowledge gained from development projects. However, they also recognised the problem of accessing the appropriate knowledge for a given situation. Interviewee ME3 also mentioned the loss of knowledge when a long-term employee retires or leaves the company. Knowledge management usually includes capturing, improving and disseminating knowledge to the appropriate people at the right time (BSI, 2001, Nonaka, 2007). A design expert (interviewee DE1) explained that design provides visual, user friendly knowledge pool for other employees, normally in the form of presentation boards, where the appropriate source of knowledge can be quickly and easily accessed. Teagarden and Schotter (2013), and interviewees DE3, DE5 and DE11, also described how design uses creative tools such as mind-mapping and brainstorming to help extract tacit knowledge from employees across different departments. This is closely related to how design encourages internal collaboration and organisational culture which results in increased innovativeness (Lemon and Sahota, 2004). Furthermore, as the source of knowledge can vary depending on the context in which it is to be used, it is also important to review the potential source of knowledge and methods to extract knowledge effectively (DE8). Design practitioners' holistic perspective of the NPD process helps them to identify the expertise required in the different stages of the process. This requires a good overview of the strength of employees or departments, hence support from senior level managers is essential to effectively working as 'knowledge agents' for the company (interviewees DE1, DE3 and DE5).

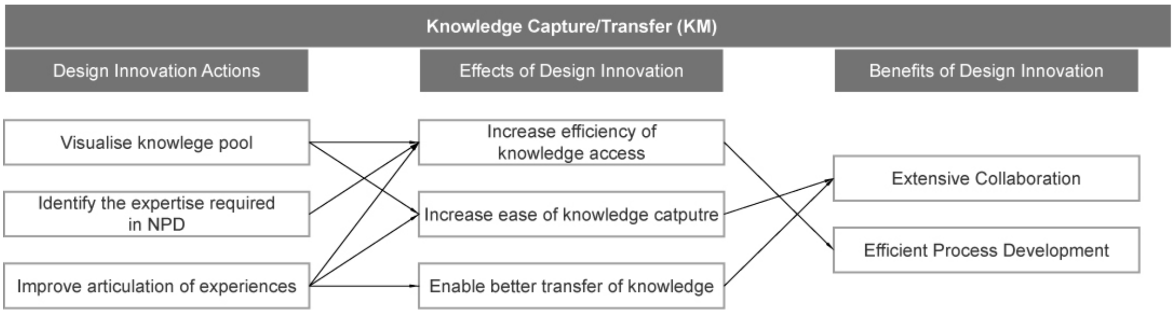


Figure 6.13: Details of design innovation characteristics for knowledge capture/transfer (KM)

Manufacturing experts acknowledged the importance of knowledge management and their desire to utilise knowledge more effectively (interviewee ME3, ME5 and ME6). However, they also feel that they currently do not utilise knowledge extensively in NPD processes and therefore often lose tacit knowledge when an experienced employee leaves the company. It is therefore vital to retain knowledge within the company and one way to achieve this is to become a learning organisation where experiences are shared in the NPD process in a collaborative environment (O'Dell and Grayson Jr., 1998, BSI, 2001). The design innovation characteristic of capturing/transferring knowledge both satisfies this need and is beneficial to enable better collaboration and efficient process development for the company (see Figure 6.13).

6.2.2.3 External collaboration

Collaboration - one of the most important contributors to innovation - is the value-adding activities of people and organisations sharing knowledge to enhance innovation (Roser et al., 2009) and competitiveness (Gouillart, 2014). The research identified two ways to collaborate: external and internal. External collaboration will be discussed here, internal collaboration in the next section. As discussed in the chapter 2, one indicator of an innovative manufacturing company for this research is whether businesses continuously demonstrate that they collaborate with external organisations. External collaboration consists of working with consumers (as individuals), organisations (both governmental and non-governmental, including universities, and advisory organisations such as The Design Council and the Business Growth Service), and other companies (through strategic alliance or as part of the client-supplier relationship). All manufacturing companies interviewed mentioned the importance of collaboration, some linking their trusted client relationships to their core competence (interviewees ME3, ME5, ME6, and ME9). The principle of external collaboration is similar to that of ‘co-creation’ where collaborative relationships are dynamic and mutually beneficial (Reinmoeller, 2002), which can be a strategic option for value creation (Payne et al., 2008). It includes (i) creativity from collaboration, (ii) advantages of drawing on marketing and management approaches, innovative processes, and knowledge and group decision marketing, (iii) taking the role of facilitator, (iv) enhanced relationships between people, and (v) learning processes (Roser et al., 2009)

The research also found that design innovation should be involved from the initiation of the co-creation process, to help identify the areas which require an external collaborator(s) (interviewees DE1 and DE3) and develop an appropriate programme or process suited to external collaboration. During the process, customers take on many roles including as initiator, co-producer and as inspiration for business development (Öberg, 2010). Design innovation actively encourages user/client involvement in the NPD process using design research methods such as workshops (interviewee DE1) or even informal conversations with stakeholders (interviewee DE3), using them almost like a gates in a stage-gate process. It creates an environment where idea-sharing is encouraged, by using tools such as brainstorming and mind-mapping (DE6). The information provided by the external collaborators is used as the basis of decision-making. At this stage, design experts DE4 and DE8 commented on the limitations of information provided by the consumers/clients whose thoughts are likely be bound within their own knowledge and experiences. Interpretation and mediation of the information is therefore important, which when managed well is likely to improve user experience (interviewer DE4) and provide effective personalisation of the product/service (interviewee DE8) which contributes towards a successful external collaboration.

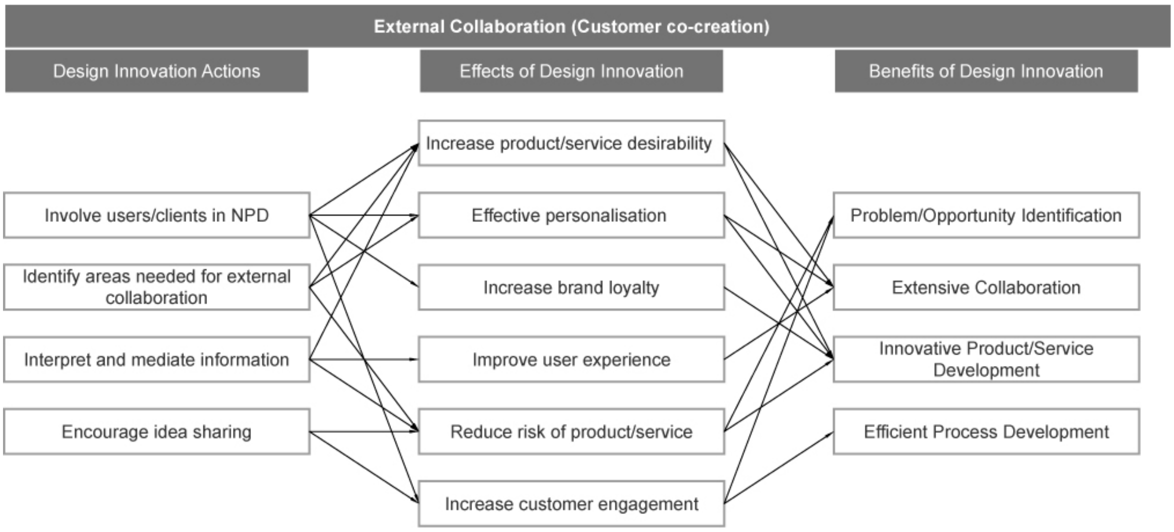


Figure 6.14: Details of design innovation characteristics for external collaboration (customer co-creation)

The design and manufacturing experts emphasised the impact of external collaboration on innovation. It directly influences problem/opportunity identification, extensive collaboration, innovative product/service development and effective process development (see Figure 6.14). The first influence (benefit) is derived from the process of reducing product/service risk in the market and also from customer engagement through their involvement in NPD and idea-sharing. Secondly, extensive collaboration occurs whilst the effects of external collaboration takes place in increasing product/service desirability, effective personalisation in product/service, increased brand loyalty and improved user experience in products/services through improved functionality, ergonomics, serviceability, the customer journey, touch-point improvements, etc. Thirdly, the research identified the influence of external collaboration in developing innovative products/services, where the continuous insights gained from collaborating with the users or other organisations at different stages of product/service development can work as signposts for successful user adaptation. Finally, the process for increasing customer engagement by design innovation actions such as involving users or clients in the NPD whilst encouraging idea-sharing, can be used to develop a more efficient user-centred process, one of the traits of successful innovative companies.

6.2.2.4 Internal collaboration

According to a recent BCG report on the most innovative companies (BCG, 2014), the successful innovating companies ensure the value of innovation is encapsulated in the corporate culture by encouraging collaboration, rewarding ideas, and capitalising on good ideas promptly with appropriate support. The report described how internal collaboration includes cross-positional and interdepartmental activities and is very closely linked with company structure, culture and the attitude of the top-level managers. Interviewee DE1 mentioned that often where departments are separated to do a particular job (silos), internal collaboration between departments can be difficult. However, he and other design and manufacturing professionals (interviewees ME2, ME3, ME5, DE2, DE3, DE5 and DE6) again emphasised the importance of internal collaboration to enable innovation. Design innovation encourages internal collaboration by using methods similar to those used for external collaborations. It acts as a mediator between departments and often between different positions in the company hierarchy (interviewee DE1). This is where cross-pollination of ideas happen. Subsequently, idea-sharing is encouraged, and in the process it helps extract implicit knowledge which encourages employee engagement and ownership (interviewee DE1), providing fresh perspectives and early detection of potential issues and problems (interviewee DE10). Design innovation can also be used to create a physical collaboration space such as break-out areas to encourage cross-departmental ideas and information-sharing (interviewee DE6). The physical collaboration space is identified as another design innovation characteristic, and will be further discussed in the next section.

Internal collaborations issues were raised by interviewees ME8 and DE9, who mentioned communication difficulties when sharing ideas between people with different professional backgrounds and conflicting agendas. The design practitioner or manager’s role in an organisation, acting as a mediator, may be restricted if s/he only works as a subsidiary of a department. The first issue is addressed by the design innovation action of synthesising ideas using visual materials to aid better communication between the stakeholders (interviewees DE1 and DE8).The second problem is much more complex and fundamental and needs to be addressed by top-level managers, by valuing design, authorising the creative process of design innovation to intervene in the collaboration processes, and actively participating in the process themselves (interviewees DE3 and DE5). Support from top-level managers is also recognised as a design innovation characteristic and will be further discussed in the next section.

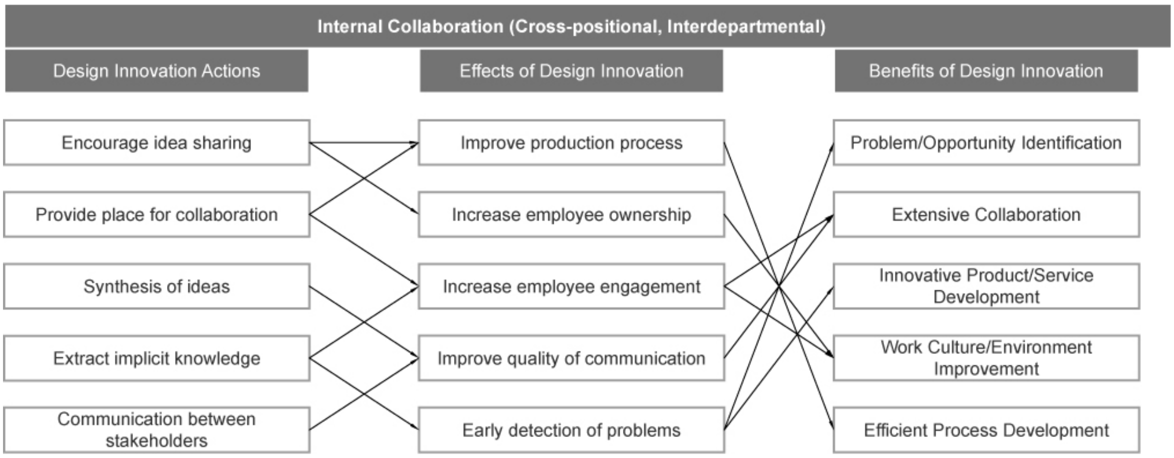


Figure 6.15: Details of design innovation characteristics for internal collaboration

The research indicates that internal collaboration as a form of design innovation characteristic provides benefits in five different areas. Figure 6.15 shows the design innovation actions and their subsequent effects as outcomes of these actions, as discussed earlier in this section. The characteristic's benefits cover a wide range of areas, including (i) improving problem/opportunity identification by detecting any potential problem early by sharing of implicit knowledge (from experienced staff), (ii) enabling extensive collaboration by encouraging and communicating well with internal staff, (iii) better development of innovative products and/or services by reducing the risk of potential problems, (iv) enhanced work culture and environment through design innovation actions to increase employee ownership and engagement, and (v) development of a more efficient process by providing appropriate places for collaboration and sharing expert ideas to improve the production processes.

6.2.2.5 Physical work environment

The research identified two major perspectives of the physical work environment as a characteristic for design innovation: cultivating creativity and increasing work efficiency. The former describes a physical work environment in terms of creating a collaborative atmosphere (Levin, 2005, von Stamm, 2008) and the latter describes optimising workflow, as part of lean manufacturing (Wilson, 2010). Von Stamm elaborates the aspects associated with the former work environment (von Stamm, 2008): (i) meeting and recreational spaces, (ii) a variety of different work-spaces, (iii) arrangement of departments, (iv) spaces dedicated to project teams, and (v) spaces dedicated to innovation and creativity. Optimising production within the lean manufacturing principle includes reducing wastes in motion (movement of people) and transportation (movement of materials) (Wilson, 2010). Interviewee ME5 described the work-flow optimisation in his company through introducing an open-plan sequential arrangement of each production stage which is logical and easy to follow. Interviewee DE2 also described a project which eventually included a production process improvement as DE2's agency was consulting on the design of medical laboratory equipment. Including design in the process of creative problem-solving, both companies achieved an increase in production efficiency by shortening the lead time. This also had positive effects on collaboration, especially for the ME2's company where the open-plan workspace provided better interaction between staff in different parts of the production process. Furthermore, as part of an internal branding exercise, interviewee DE1 explained design's prominent role in conveying the right brand message to the employees by using visual communications with cues of the company's vision and values. By understanding the users' (employees') needs for a more creative workspace, DE1's agency provided flexible working-space where creativity is encouraged. Another action of design innovation is providing a space for collaboration e.g. break-out areas designed specifically to provide space for employees to meet and interact, creating natural spaces for collaboration (interviewee DE6).

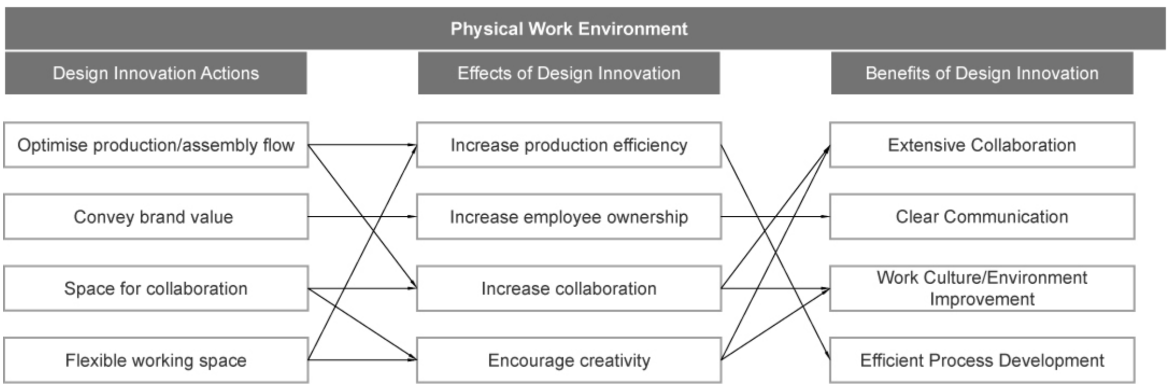


Figure 6.16: Details of design innovation characteristics for physical work environment

The benefits of an improved physical work environment through design innovation actions are (i) extensive collaboration by physically placing people together to encourage interdepartmental integration, (ii) clear internal communications conveying brand values which increase employee ownership, (iii) work culture/environment improvement though flexible working and collaborative spaces to provide a creative working environment, and (iv) efficient process development by minimising wasted movement of both employees and materials (see Figure 6.16). Although the physical work environment was mentioned in the interviews less often than other characteristics, workspace design should be regarded as part of strategic decision, acknowledging that it can support the company's processes, structure, strategies, people (employees), and reward system where designers make a value-added contribution (Levin, 2007). Furthermore, according to Waber et al. (2014) the importance of the workplace is its quality of encouraging the collaborations and knowledge transfer which are essential in cultivating innovation.

6.2.3 Characteristics in 'corporate-level design thinking for organisational innovation' area

In this section, further design innovation characteristics are discussed which are mainly within the boundary of 'designing for technological/product/service innovation' area in the design innovation spectrum including: (i) top-level management support, (ii) investments, (iii) company vision/values, (iv) Unique Selling Proposition (USP), and (v) business model (Table 6.5). Design innovation characteristics placement within the design innovation spectrum is further discussed in Section 6.3.

Table 6.5: Design innovation characteristics within the 'corporate-level design thinking for organisational innovation' area of the design innovation spectrum

Design Innovation Spectrum	Design Innovation Characteristics	Place of immediate change (impact)
Corporate-level design thinking for organisational innovation	Top-level management support	Internal
	Investments	Internal and external
	Company vision/values	Internal and external
	Unique Selling Proposition (USP)	Internal and external
	Business model development	Internal and external

6.2.3.1 Top-level management support

Top-level management which values design and its capability in increasing innovativeness of the company is an essential characteristic of design innovation. This was suggested by manufacturing experts ME3 and ME5, a point strongly emphasised by interviewees DE2 and DE4 and almost all the other design experts. Support from top-level managers is important because it encourages creative ideas generation and collaboration which enable the company to build its innovation culture (Euchner, 2013) and influence employees' innovative behaviour (de Jong and Den Hartog, 2007), and is regarded as the most important critical innovation ingredient (von Stamm, 2008). The design and manufacturing experts agreed on the beneficial effects of top-level management support, and the design experts particularly commented that the application of design thinking principles by top-level managers on management practices, regardless of whether knowingly or not, would be advantageous in prioritising innovation (interviewees DE1 and DE3) and building a design-minded organisation (Lockwood, 2009). The business leaders using design principles to solve business problems - also referred to in this research as corporate-level design thinking - provides an empathetic user-centred approach to problem-solving (interviewees DE1, DE5, DE6, DE7, DE8 and DE11), where the users can be the customers buying products/services or the company's employees. This leads to the transformation of an organisation towards embracing innovation across the whole company (Brown, 2009, Topalian, 2012). Design innovation actions to achieve this include aligning strategic decisions to encourage collaboration both internally and externally by rewarding innovation appropriately to enable an innovative work culture (interviewees ME9, DE1 and DE8). Further actions of top-level management support which contribute to creating an innovative work culture include providing a consistently challenging company vision to stimulate the employees (interviewee DE8).

Top-level management support influences all six design innovation benefits either by providing direct, primary influences or secondary influences derived from or as by-product of the primary benefits (see Figure 6.17). The primary benefits influenced by the top-level management support include problem/opportunity identification, extensive collaboration, work culture/environment improvement and efficient process development. These benefits are result of the design innovation actions and subsequent effects as identified earlier in this section. The secondary benefits indirectly influenced by the top-level management support include clear communication and innovative product/service development. The clear communication is necessary while extensive collaboration, encouraged by the top-level management takes place to ensure the purpose of the collaboration is clear among participating departments and professionals. Therefore, the clear communication is a by-product of the extensive collaboration. Innovative product/service development is derived from problem/opportunity identified by encouragement of creative idea generation, and efficient process developed through encouragement of collaboration by the top-level manager. Hence the innovative product/service development is indirectly influenced by the top-level management support.

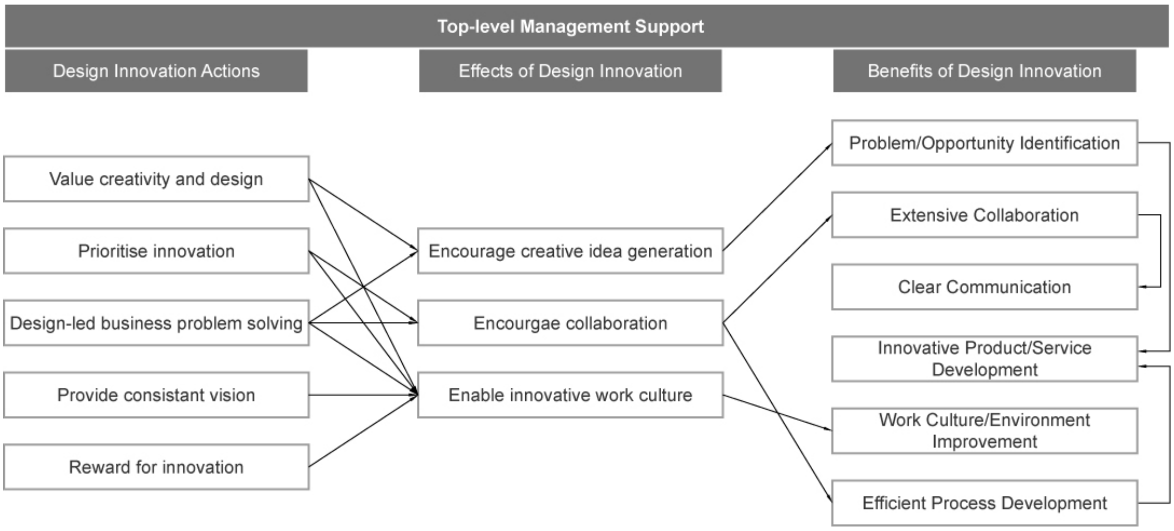


Figure 6.17: Details of design innovation characteristics for top-level management support

6.2.3.2 Investments

The research identified two different investment areas as a design innovation characteristic: firstly, the manufacturing company's investment and management of resources for design, including investment in computer software and subsequent training to increase CAD capabilities (interviewees ME2 and DE2), and providing creative space to encourage collaboration (interviewee DE6). Investment in design expertise is a design innovation action which includes working with external agencies to create better quality products/services (interviewees ME3 and ME5) and hiring new design professionals to improve the product/service development process (interviewee ME4). Active research is now being conducted to identify the value of investing in design (return of investment-ROI); The Design Council claims that £1 of design investment returns £20 in revenue (DC, 2012a). More recently, the Design Management Institute (DMI) found that design-conscious companies perform 228% better than non–design-conscious companies (Rae, 2013). Despite these results, Bruce el al (1995) argue that design investment is one of the first casualties of cutbacks during a recession. Interviewee DE4 concurred with this, mentioning the design cutbacks even in large multinationals during the recent recession. Investment in design resources and expertise are nevertheless necessary in order to effectively cultivate design innovation in a company and also it is low risk and high reward investment (Bruce et al., 1995).

The second area of investment as design innovation characteristic is the use of design as a research mechanism to identify investment areas, similar to technology scouting. Often there are budget constraints, so managers must carefully prioritise to ensure that investment is used as effectively as possible. Traditional business decision-making relies on rigorous and analytical research, but when this is combined with design methods - which tend to use more qualitative approaches to discover market and user insights - more successful decision can be made (Chhatpar, 2008). Interviewee ME3 demonstrated this: his company purchased a machine after careful consideration in partnership with a design professional. The effect of design investment includes enhanced profitability (DE6, DE7 and DE8) and improved product/service development processes (ME3 and DE1).

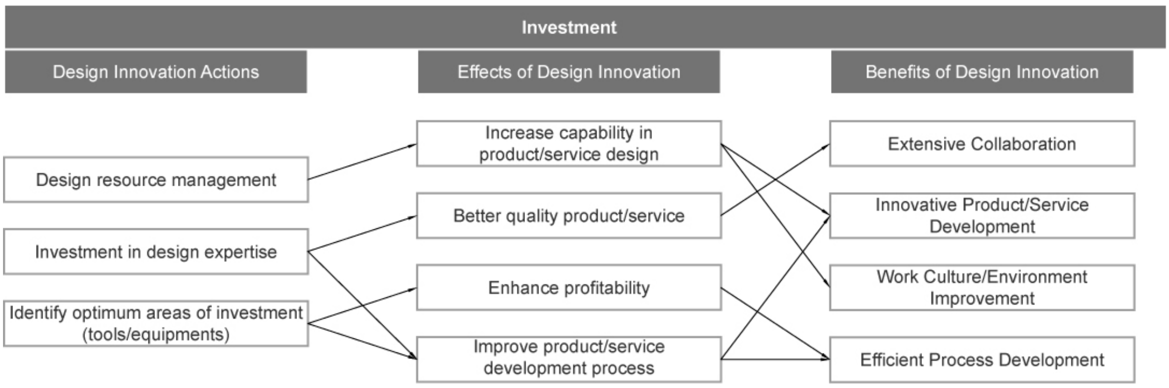


Figure 6.18: Details of design innovation characteristics for top-level management support

The benefits of design innovation through investment to improve innovativeness are shown in Figure 6.18: (i) extensive collaboration through working with external and internal design professionals to create better quality products/services, (ii) innovative product/service development as a result of increased capabilities in design and an improved development process, (iii) work culture/environment improvement through enhanced collaborations, and (iv) efficient process development through optimised investment for the business to improve product/service development process and support from design expertise.

6.2.3.3 Company vision/values

Clear company vision and values play an important role in developing the company's strategic direction (Witcher and Chau, 2014). Companies with long-term successes typically have vision and value with dynamic strategies which continuously adopt to a changing environment (Collins and Porras, 1996). The design innovation characteristic comprises two types of actions towards vision and values: firstly, it is an agent of communication. Design practitioners use vision and value as part of branding, conveying the message both internally and externally through products, services and/or promotional materials to increase brand awareness (interviewees ME7, DE5 and DE10). Sawhney and Prahalad (2010) found that design practitioners advocate communicating the vision and value of a company to consumers. The second type of design innovation action is to assist in creating a company's vision and values by acting as a mediator between the top-level managers and employees or customers. Design consultants who are familiar with business environments, with extensive experience in the industry, help small or medium manufacturing companies to create or redefine vision and values (interviewees DE3, DE6 and DE8). As design thinkers, a primary consideration when helping manufacturing companies to create vision is to consider the customers (interviewee DE6). The vision is therefore intrinsically customer-focused. Moreover, as the company values are at the core of a company – the source of strategies in branding, product and operations - key values are carefully assessed to reflect the company's 'real' values. Collins (1996) suggests that 'fake' values are quickly noticed both internally and externally. Interviewee DE1 cited the example of a project where a wide range of employees was engaged in developing a company vision, resulting in increased sense of employee ownership towards the company.

The primary benefits of the design innovation characteristic of improving company vision/values are clear communication and work culture/environment improvement (see Figure 6.19). Design innovation both increases internal and external brand awareness and guides focused decision-making for manufacturing companies. This characteristic has secondary benefits where an innovative work culture enables the company to identify opportunities through an improved, customer-centred focus to concentrate its resources on fulfilling the new company vision. Clear communication of company vision and values can thus provide improved shared understanding between collaborators, enabling better extensive collaboration. Furthermore, improvement in work culture through an increased sense of company ownership among the employees also provide more engagement for extensive collaboration.

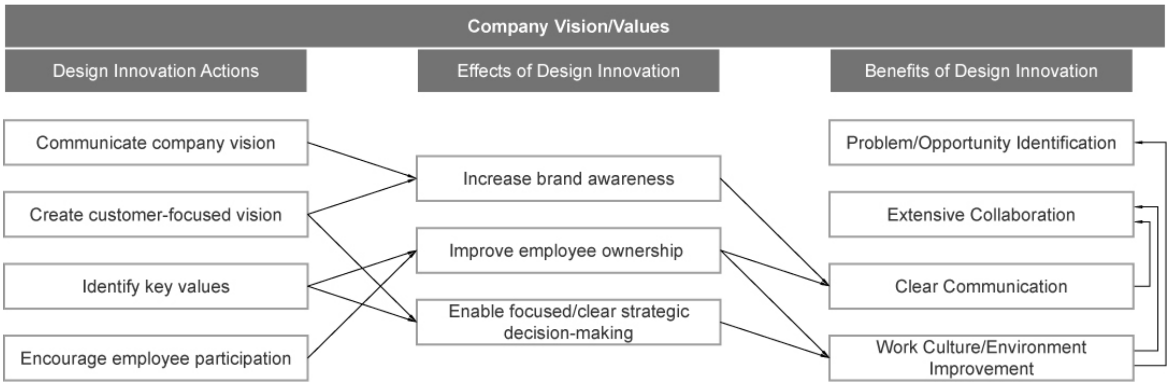


Figure 6.19: Details of design innovation characteristics for company vision/values

6.2.3.4 Unique Selling Proposition (USP)

The unique selling proposition (USP) – described by the Chartered Institute of Marketing as “one of the basics of effective marketing and business that has stood test of time” (CIM, 2009:2) - manifests a company’s unique differences among competitors. Manufacturing companies can have USP in price, quality, reliability, customisation, and even the flexibility to produce small batches to meet clients’ requirements (interviewee ME5). However, this area is often overlooked by some manufacturing companies, because they are comfortable in the products/services they already produce (interviewee DE1). Even innovative manufacturing companies, once recognised for their innovation, can rapidly become stale because they are in ‘algorithm’ stage (i.e. a simplified task with a fixed formula which is most efficient, but has no growth) within the ‘knowledge funnel’ (Martin, 2009). The USP can quickly become a mundane proposition as the competition catches up, leading the company to face difficulty surviving in the market. According to design and manufacturing experts (interviewees ME2, ME5, ME9, ME10, DE1, DE7 and DE11), it is therefore essential for companies who want to be continue to be successful in the market to reinvent their USP or seek a USP in existing products. The USP must be also be communicated clearly both internally and externally to increase the brand value, and internally to give employees a sense of pride (interviewee DE1), and externally to provide market competitiveness (interviewees ME5, DE1 and DE8).

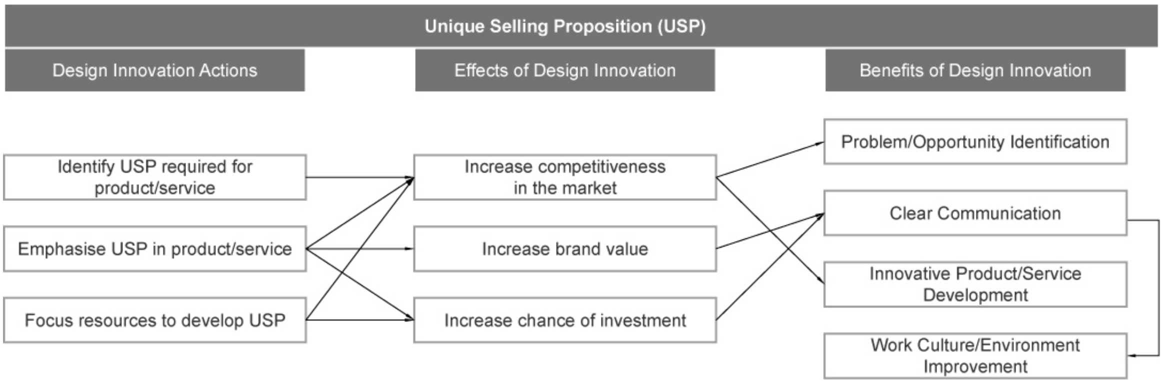


Figure 6.20: Details of design innovation characteristics for the USP

The primary influence of USP as a design innovation characteristic is on problem/opportunity identification, clear communication and innovative product/service development (Figure 6.20). While identifying and developing a USP, the company will gain market knowledge and access potential new markets, creating new opportunities to exploit. Communicating USP will also increase brand value and, in conjunction with a viable business model and creative graphics, help the company obtain investment and thereby achieved clear communication of the USP. Focusing resources to develop USP will bring internal staff together, with a heightened sense of pride through clear communication, and the work culture/environment improvement will be a secondary beneficiary.

6.2.3.5 Business model development

In recent years, partly through the “dot.com boom”, the business model has been popularised as a way of convincing investors how a business can make a profit (DaSilva and Trkman, 2014). The business model consists of nine key ‘blocks’(Osterwalder and Pigneur, 2010): customer segment, value proposition, channels, customer relationship, revenue stream, key resources, key activities, key partnerships and cost structure. The ‘business model canvas’ is created using these blocks to assess and develop business models, which have gained popularity in design community because it provides a holistic overview of business operations (Simonse, 2014). The business model can both facilitate and represent innovation (Teece, 2010) where technological innovation require a business model in order to be successful in the market. The business model itself can also represent a form of innovation, so business model innovation is regarded as an innovation with similar or sometimes stronger emphasis in order to be innovative in a competitive market (Chesbrough, 2007). Many of the design experts agreed with this (interviewees DE1, DE2, DE3, DE5, DE6 and DE8), citing experiences of being involved in creating part of a business model for client companies by identifying a new sales channel and customer touch-points with their design work for manufacturing companies. This increased efficiency in the value chain by reducing unnecessary operational steps (the lean process), and in the customer base by delivering products/service via new sales channel with better touch-points to attract new users. These segments of the business model are evidently an important part of the design process, where understanding user and market needs and designing to satisfy them naturally brings design professionals to consider sales channels and consumer touch-points. Design can also provide a holistic overview of the business itself, thereby creating the business model best suited to the varying situations of different individual manufacturing companies (interviewees DE5 and DE8). The use of design research tools in building the model is demonstrated by Simonse (2014), including the actor map (e.g. Net-Map) which captures how and why the transaction between influencers and stakeholders are interlinked, role perspectives (e.g. IDEO’s Human Centered Design toolkit) which provides different perspectives on a situation through stakeholders with insights in a network or community, and activity maps (e.g. customer journey mapping) offering a visual illustration of insights into customer activities and purchase behaviours.

The business model development as a design innovation characteristic provides four benefits (see Figure 6.21). Firstly, in problem/opportunity identification it provides a holistic view of current business operations and identifies possible development area(s). Secondly, clear communication through visual representation of the business model enables the key stakeholder in the company to grasp the complexities of the overall business model, whilst building the business model. Thirdly, it can develop the customer-centred innovative product/service development; and lastly, it can develop an efficient process through increased efficiency in the value chain.

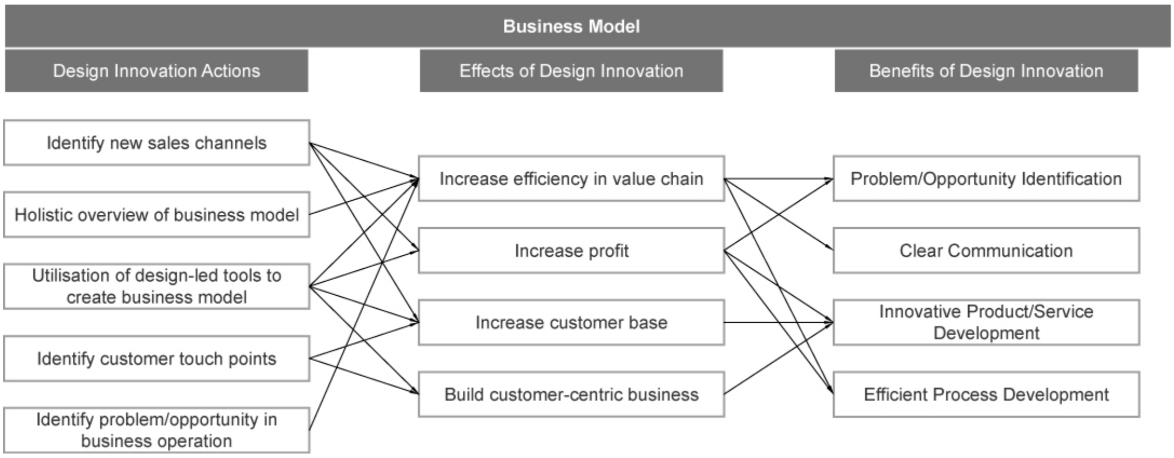


Figure 6.21: Details of design innovation characteristics for business model generation

6.3 Design innovation characteristics in the Design innovation spectrum

The design innovation characteristics are formulated using the interviews with experts and literature data to provide a comprehensive list of design innovation benefits for UK innovative manufacturing companies. As they were formulated, each one was placed in the design innovation spectrum (see Chapter 5) in order to identify where each characteristic can be positioned in a business context. Figure 6.22 shows the placement of the characteristics according to their actions and business benefits and its position in a given business level, and the main persons involved in furthering the characteristic. In this integration process, the research discovered that the design innovation actions and their subsequent effects and benefits do not necessarily conform precisely to the design innovation spectrum. Their influence is wider than a single area of the spectrum e.g. the external collaboration as a design innovation characteristic includes involvement of users/clients in NPD, which affects personalisation and is beneficial in developing innovative products/services. This sequence of action and effect means the characteristic can be placed both in 'designing for product/service innovation' and 'design strategy for process innovation'. It is nonetheless still useful to superimpose the characteristics on the spectrum, to provide an important overview of the extent of design influence in businesses. However, the characteristic placement is inherently flexible as it is heavily dependent on a manufacturing business's circumstances and context. It should therefore be viewed as an illustration of the probable connection between the design innovation spectrum and each design innovation characteristic.

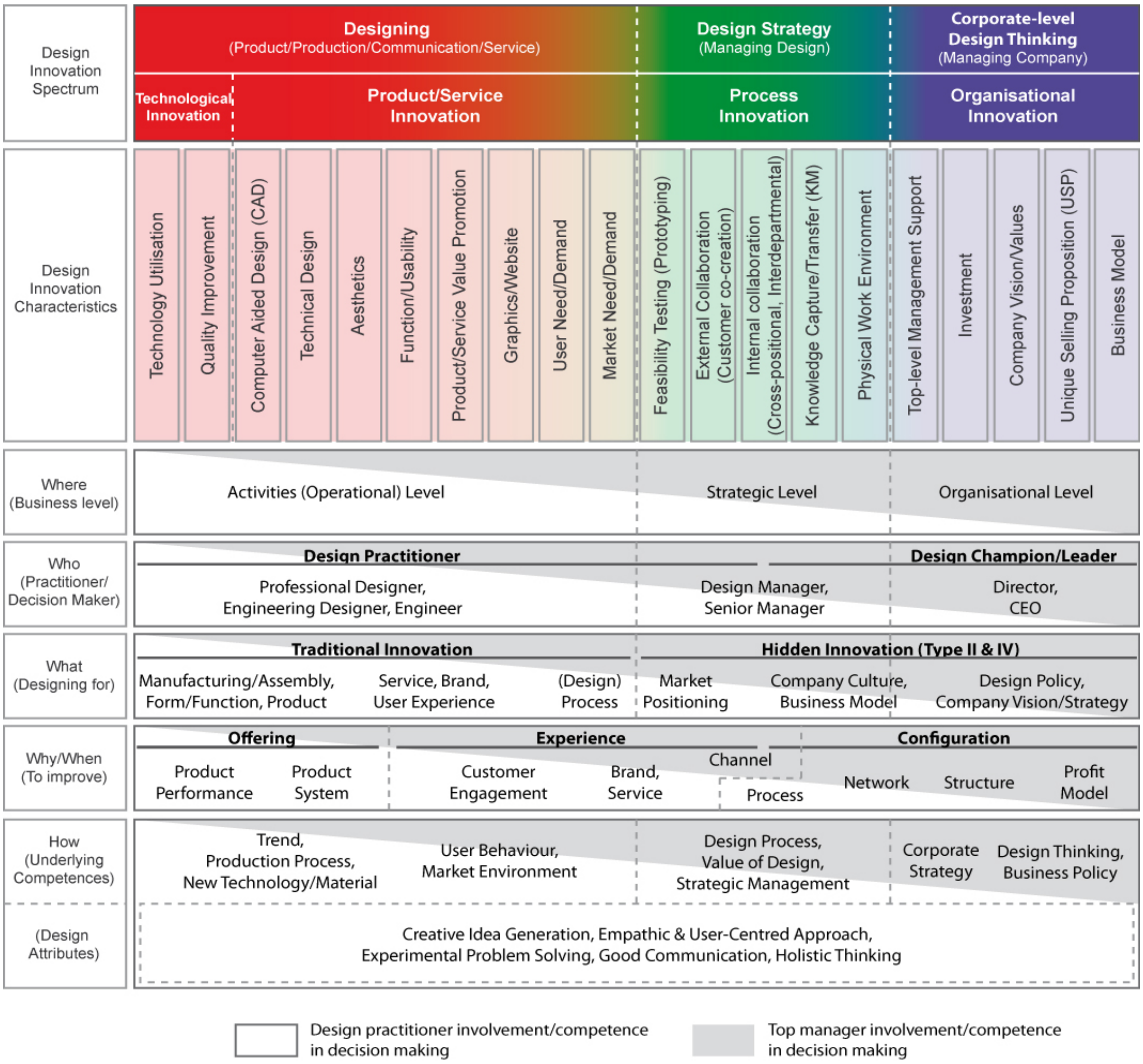


Figure 6.22: Design innovation characteristics in the design innovation spectrum

6.3.1 Designing for technological/product/service innovation

The majority of the characteristics identified in this research can be placed under the 'designing for technological/product/service innovation' area of the design innovation spectrum. This is expected because manufacturing companies readily utilise this portion of the design innovation spectrum as a major part of “traditional innovation” (NESTA, 2008b). Manufacturing companies can easily grasp the meaning of design here, as it deals with the physical process of visualising the idea to make production-ready drawings. The design innovation characteristics in this area probably occur towards the latter stages of a design process, near the production of products/ services, with actions which ‘shape’ the product/service to be launched, i.e. its function, aesthetics, product value, interface, etc., The main users of these characteristics are the design professionals, engineering designers or engineers, as identified from the design innovation spectrum, predominantly at an active (operational) level of business.

Both design and manufacturing experts broadly agreed on the benefits of design innovation in this section. The only discrepancy was with the ‘technology utilisation’: none of the manufacturing experts mentioned any possible benefits of using design to help the company better utilise technology through scouting and correctly adopting appropriate technologies, to create technologically advanced products or improve production. In contrast, the design experts shared their experiences with manufacturing companies to identify and use new (relative to the company) technologies to improve products, and also identify R&D areas for manufacturing companies to further investigate to benefit the users and be successful in the market (see Section 6.2.1.1).

The characteristics of understanding and accommodating user and market needs and demands are included in the ‘designing for technological/product/service innovation’ area of the spectrum, but it can also be seen as part of the ‘design strategy for process innovation’ area. Although the execution of the information gathered from these characteristics is a critical part in ‘designing’ to provide ‘product/service innovation’, data gathering is also an important part of ‘process innovation’.

6.3.2 Design strategy for process innovation

The characteristics identified under the ‘design strategy for process innovation area’ of the design innovation spectrum consist mainly of the how the ideas are formulated to become a viable option for further development. This includes feasibility testing, external collaboration, internal collaboration, knowledge capture/transfer and the physical work environment. As mentioned in the previous chapter, the decisions are likely be made at the strategic level of a business by design managers or senior managers who are competent in process development and management, as described in the design innovation spectrum. In this important area for developing the culture of creativity and innovation, the design practitioner plays a vital role as a mediator. The presence of a design champion is most effective here, according to design experts (interviewees DE1, DE2 and DE3), as they can influence processes (including new product development, production, delivery, etc.) to satisfy both business and user requirements by effectively balancing the opinions of the company's top-level managers and design practitioners. Internal collaboration (cross-positional and interdepartmental) is a key to achieving this, where the design champion also has the dual role of facilitator and mediator, advocating design thinking so that it can be effectively integrated in different processes in the manufacturing business.

The research found that there are two major purposes in the innovation process. Firstly, the employees, the people who make the product/service: most of the effects of the characteristics in the 'design strategy for process innovation' area point towards employee loyalty, ownership, and engagement through better communications and collaboration. Its purpose is to maximise creativity by applying design methods readily used by the design practitioners to share ideas (obvious examples are brainstorming and mind-mapping in a workshop environment), in order to develop product/service which is creative and successful in the market, while reducing the risk of failure, i.e. innovative products/services. Secondly, the physical process of improving production efficiency. This is similar to the idea of lean manufacturing or the Toyota Production System (TPS) by reducing waste (transport, inventory, motion, waiting, overproduction, over-processing and defects) in the production process. The principle of design can also be adopted to identify problem/opportunity areas by viewing the process as a system similar to customer journey-mapping to understand the process more deeply. As mentioned earlier, the designer can be a facilitator, making the process more efficient, but it will be impossible to provide technically viable solutions. Internal collaboration is crucial to maximise the effectiveness of the process, and designers can elicit creative solutions which can contribute to making the process more innovative.

6.3.3 Corporate-level design thinking for organisational innovation

Organisational innovation involves management of the entire company (see Chapters 2 and 5). The main decision-makers are the top-level managers who have an operational overview of the company and are therefore entrusted with making judgements about the direction the business should move forward in. However, the research also found that this area of the design innovation spectrum is less likely to be the place where design has influence because of the limited perception of design, of its capability to draw out people's creativity, regardless of their background profession, especially with top-level managers. On the contrary, the practice of design thinking in the management discipline has been expanding where many business schools, especially in the US, adopt this idea and teach design thinking as part of the MBA curriculum. This principle of design thinking is described in this research as 'corporate-level design thinking' which manifest that the influence of design is no longer just on creating products/services by adding value; it now also influences building a company which is creative and therefore innovative.

The characteristics identified in this area of the design innovation spectrum include top-level management support, investment, company vision/values, USP and the business model. Among the design experts' most popular discussions was top-level management support, user need/demand and the business model, to enable design innovation in a manufacturing company. They argued that without buy-in from top-level managers, it is almost impossible to cultivate innovation. Top-level managers' mindset or attitude towards design and organisational change are vital from the outset, to improve a company's innovativeness. A design leader must embrace design innovation and integrate its benefits into the company to provide competitive advantage in a competitive market. Once that support is established, design innovation can start implementing design methods and principles to support the development of company vision and values, USP and a business model which is relevant to current market trends and customer needs, with a holistic overview of the position of the business and the direction it may take to stay ahead of competition or discover new markets, to maximise the company's current competence - and investment can be made where the most value can be obtained.

6.4 Chapter summary

This chapter has discussed in detail the development of design innovation characteristics through the literature review and expert interviews, and the integration of the characteristics with the design innovation spectrum created in Chapter 5.

The twenty design innovation characteristics identified in this chapter are: technology utilisation, quality improvement, computer aided design (CAD), technical design, aesthetics, function/usability, product/service value promotion, graphics/website, user need/demand, market need/demand, feasibility testing (prototyping), knowledge capture/transfer (KM), external collaboration, internal collaboration, top-level management support, physical work environment, investment, company vision/values, the unique selling proposition (USP) and the business model. Design innovation actions to develop these characteristics were also identified with their subsequent effect and benefits to an innovative manufacturing company. The design innovation characteristics provide a comprehensive overview of the influence design innovation can have, ranging from technical design to business model generation, to encourage innovation and thereby increase competitiveness and growth.

The next chapter discusses recommendations, through the development of a design innovation framework, and implementation guidelines. The evaluation of the framework and its implementation with experts in design innovation is also discussed, to provide a final design innovation framework and its implementation guidelines.

Chapter 7. Discussion and Recommendations

7.1 Introduction

The research constructed a comprehensive overview of design innovation in UK innovative manufacturing companies by creating a design innovation spectrum covering: (i) designing for technological and product/service innovation, (ii) design strategy for process innovation, and (iii) corporate-level design thinking for organisational innovation. Some twenty design innovation characteristics were identified to provide details of actions and the effects of design innovation on the companies. This chapter synthesises and discusses the findings, to create recommendations in the form of a design innovation framework and suggest implementation measures, which innovative manufacturing companies can adopt in order to increase the innovativeness of their company.

Table 7.1: Brief index of evaluation experts in design innovation and manufacturing

Interviewees	Organisation
EE1, EE2, EE3, EE4	UK innovative manufacturing businesses (top-level managers)
EE5, EE6, EE7	UK innovative manufacturing businesses (senior/middle managers in design)
EE8, EE9, EE10	UK design consultancies (top-level managers)

Note: See Chapter 3 for detailed descriptions of the interviewees

The framework was evaluated by ten design innovation and manufacturing experts, prospective users of the framework (Table 7.1). The interview used an in-depth semi-structured format to identify the framework's comprehensiveness, acceptability, feasibility and usability. Information gathered from the interviews was used to make adjustments to create the final design innovation framework and implementations for innovative manufacturing in the UK.

Figure 7.1 outlines Chapter 7.

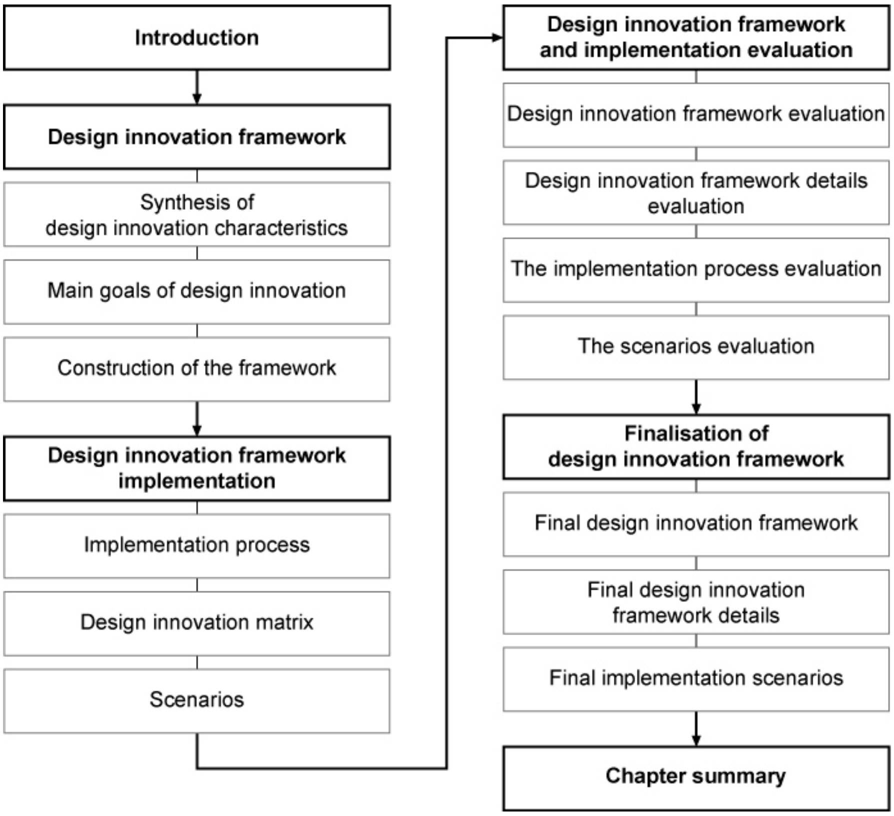


Figure 7.1: Chapter map

7.2 Design innovation framework

The design innovation framework is intended to provide a holistic overview of design innovation benefits for UK innovative manufacturing companies. It is designed as a guide to identify and further improve a company's technological, product/service, process and organisational innovation by utilising designing, design strategy, and corporate-level design thinking which are part of the design innovation spectrum. The framework includes twenty design innovation characteristics which lead to six essential benefits for manufacturing companies to achieve three main goals to improve innovativeness. The framework also demonstrates the influences of design innovation characteristics on six design innovation benefits. The design innovation characteristics span across the design innovation spectrum, which helps identify design innovation in a business context, including the influences of design (output) and the requirements for design (input). The subsequent six benefits of design innovation are identified from the characteristics which provide the improvements a company can expect from using good design innovation practices. These benefits can help the company to achieve three main design innovation goals: (i) optimisation of the business environment, (ii) generation of creative ideas, and (iii) successful commercialisation. Combinations of these areas will enhance product/service, process and organisational innovation improvements and ultimately enable the company to become a practitioner of ‘Total design innovation’ which encourages growth and increases global competitiveness.

7.2.1 Synthesis of design innovation characteristics

The design innovation characteristics were created by analysing literature, and in-depth interviews with both design innovation and manufacturing experts purposively selected to provide a comprehensive reliable list of characteristics, including design innovation action, effects and benefits. The design innovation benefits were created using selective coding (Chapter 3) including: (i) problem/opportunity identification, (ii) extensive collaboration, (iii) work culture/environment improvement, (iv) efficient process development, (v) clear communication, and (vi) innovative product/service development. These benefits are derived from the action and effect of design innovation which form the design innovation characteristics. The actions and the effects determine whether the characteristic influences directly or indirectly to create benefits for design innovation for the companies. A graphic representation shows the synthesis of the influences of different design innovation characteristics for each design innovation benefit (Figure 7.2).

The design innovation benefit wheel contains all twenty characteristics identified by the research, and encompasses the design innovation spectrum to show the characteristics in a business context (Section 6.3). The placements are flexible, depending on how they are implemented in various innovative manufacturing companies, so the research views this as a loose categorisation of the design innovation characteristics, allowing an overview of all twenty characteristics according to the business context. The design innovation benefit wheel also shows the direct and indirect influences of the design innovation characteristics on particular design innovation benefits, and whether they manifest mainly internal, external or internal and external research/data/action, as described in Section 6.2. It is a template for providing design innovation framework details, illustrating the relationship between design innovation characteristics and the main benefits.

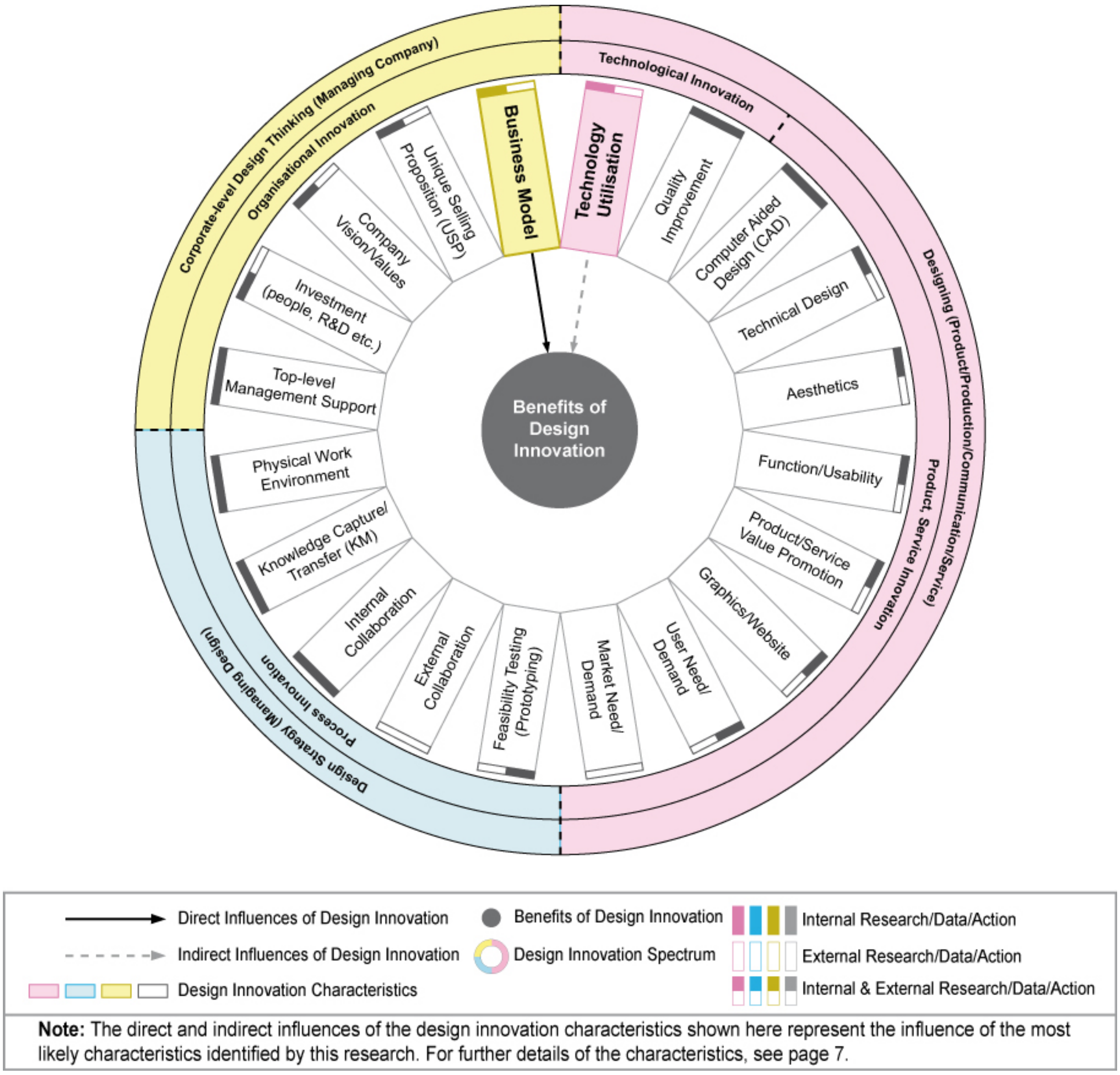


Figure 7.2: Design innovation benefit wheel

(Note: the legend applies to all design innovation wheels in this chapter)

7.2.1.1 Problem/opportunity identification

The research found that design innovation enables innovative manufacturing companies to identify problems and/or opportunities for the business. In order to achieve this through design innovation, the following design innovation characteristics should be considered: (i) understanding the *users' and markets' needs/demands*, (ii) early and frequent *prototyping*, (iii) *internal and external collaboration*, extracting and appropriately using implicit knowledge and experiences within NPD and production process, (iv) valuing creativity and design and using design-led business problem-solving by *top-level management*, (v) identifying and focusing on the *unique selling proposition (USP)* of the company, and (vi) identifying new sales channels and analysing business operations by creating a *business model* using design-led tools. The indirect influences of the design innovation characteristics were also found while: (i) scouting for new/relevant technologies to use in NPD, and to identify technology gap for new R&D project for *technology utilisation*, and (ii) creating customer-focused *company vision* with employee participation. These influences are shown in Figure 7.3.

Figure 7.3: Design innovation benefit wheel for problem/opportunity identification (design innovation framework detail)

Design innovation influences the company to identify problems and/or opportunities for developing products/services. However, some elements enable design innovation to identify problems/opportunities in production processes by encouraging internal collaboration, and in business management by using design-led tools to analyse business operations. As design is generally considered a problem-solving process, identifying problems is a key asset of design in increasing innovation in companies (Cooper and Press, 1995, Rassam, 1995, DTI, 2005, Mozota, 2006, DC, 2007, DC, 2008b, Neumeier, 2008, Brown, 2009, DC, 2010, Liedtka and Ogilvie, 2011, Mootee, 2013, DC, 2014). Problems/opportunities can be identified in many ways in business. Some use a systematic approach: a Quality Assurance (QA) department or by running Total Quality Management (TQM) programmes to ensure potential problems are identified. These approaches are both detailed and holistic in nature. However, design professionals' skill sets of creativity and thinking "outside the box" can also provide a perspective which brings new meaning to products/services (Verganti, 2006) and ensure that creativity is transferred in generating new ideas to improve product/service innovation and organisational innovation.

7.2.1.2 Extensive collaboration

The recommendation for achieving extensive collaboration through design innovation comes from its characteristics, including: (i) involving users/clients in NPD while interpreting and mediating information during *external collaboration*, (ii) *internal collaboration* i.e. communicating with stakeholders and extracting implicit ideas from employees whilst helping the company provide appropriate settings for collaboration and synthesising information gained from the collaboration, (iii) encouraging articulation of employees' experiences (implicit knowledge) and visualising this pool of knowledge to be easily accessible and applied in appropriate areas of business as part of the *knowledge capture/transfer* initiatives, (iv) involvement in optimising production/assembly flow and designing a flexible and collaboration-focused work-space to build creative *physical work-spaces*, (v) *support from top-level management* through their commitment to prioritising innovation, and applying design-led business problem-solving, and (vi) *investment* in design expertise (design champions) internally and/or externally to plan and manage internal and external collaborations through design initiatives. The secondary or indirect influences of design innovation characteristics in encouraging successful extensive collaborations are: (i) *product/service value promotion* which communicates appropriate information visually to the stakeholders (collaborators) to enable effective value creation, and (ii) applying appropriate *graphic* techniques to clearly communicate the necessary information to stakeholders including the *company vision and values*. The influences of the design innovation characteristics on extensive collaboration are shown in Figure 7.4.

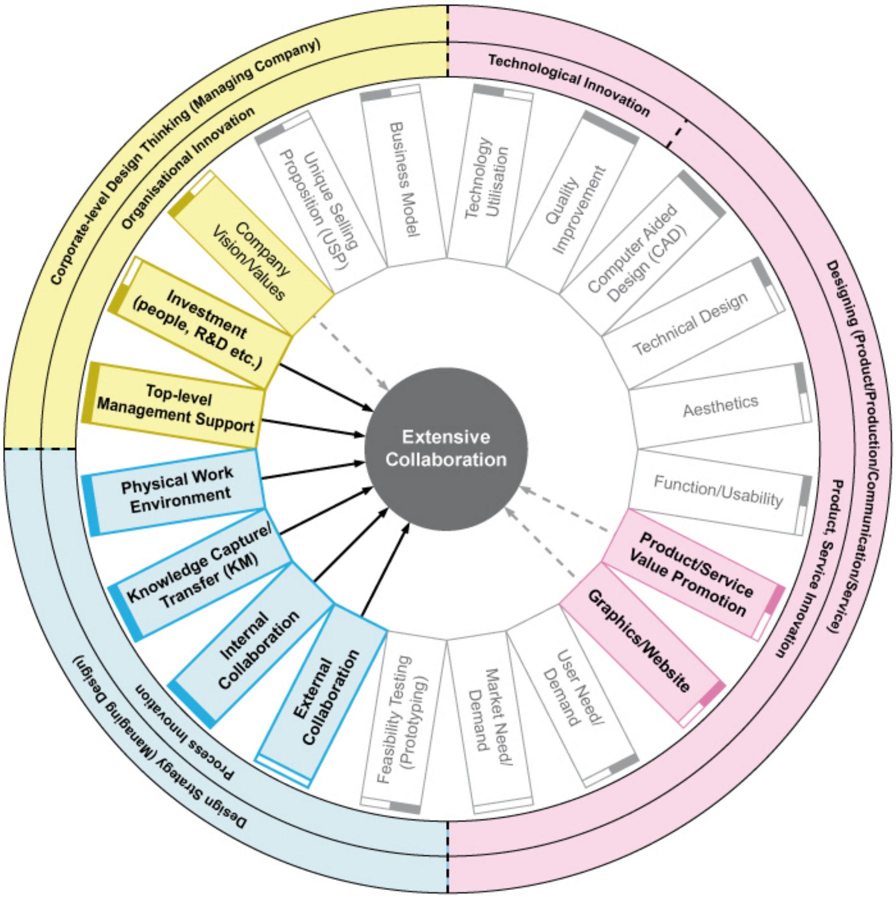


Figure 7.4: Design innovation benefit wheel for extensive collaboration (design innovation framework detail)

Collaboration is undoubtedly important for improving innovativeness by helping the company understand users' and/or clients' preferences, and to extract and use knowledge and experience from inside as well as outside of the company (von Stamm, 2008, Roser et al., 2009, Gouillart, 2014). The research found that collaboration can be used much more broadly in innovative manufacturing companies through design innovation. Design innovation encourages creative idea generation through various collaborations, by planning, recruiting (stakeholders), mediating, and analysing for collaboration and helping the company to provide an appropriate physical space for collaboration to be effective in generating creative ideas. These ideas, whether for developing a product/service, process or strategic business decisions are used to both enhance the chance of market success and optimise the business environment. It was noticed, however, that caution is required when conducting collaboration, where misunderstanding values and objectives and a badly managed process can drain resources, becoming unproductive and failing to bring insights to the company. The research therefore argues that careful planning and execution - by understanding the stakeholders with appropriate top-level management support and investment - are needed for extensive collaboration, to yield the desired outcome of generating creative ideas.

7.2.1.3 Work culture/environment improvement

The research recommends that design innovation be implemented to enable a better work culture/environment, which is essential for creating an innovative culture in a company (Figure 7.5). The focus of design innovation to bring benefits was in building an environment which provides an exciting workplace to encourage collaborations across the company. The primary (direct) influences of the design innovation characteristics include: (i) using the *graphics/website* to provide clear and consistent internal branding with an engaging internal website, (ii) encouraging *internal collaboration* through idea-sharing which enables implicit knowledge to become explicit e.g. by providing a better *physical work environment* such as a place for collaboration and flexible work–spaces, to increase employee ownership and engagements and encourage creativity, (iii) *top-level management*'s commitment to creativity, design and innovation and providing consistent messages about the *company vision and values* while encouraging employees' participation in their creation, and (iv) appropriate investment in design resources - design here includes product design and internal branding, providing space for collaboration and effective internal communications. The indirect influences of design innovation characteristics are: (i) understanding the users' (in this case, employees') needs and demands, and (ii) clearly communicating the USP to the employees, to increase the company's brand value.

Employee participation, ownership and loyalty are essential in creating an innovative work culture/environment. Design innovation and manufacturing experts and many literatures (Amabile, 1998, Howkins, 2002, Luecke, 2003, Kelly, 2006, Meyer and Marion, 2010, Enkel et al., 2011, Choi and Moon, 2013, Topalian, 2013, BCG, 2014) concur that people are the primary source of creativity and innovation. To encourage creative idea generation, the company needs the appropriate culture and environment to cultivate ideas. Design innovation focuses on this particular aspect of encouraging creative ideas by providing physical spaces, increased sense of ownership which enables increased participation by clearly communicating the vision and values through internal branding, and managing internal collaboration by using design-led tools, often in a workshop environment. The researcher therefore recommends that innovative manufacturing companies consider the value of the work culture and environment by systematically applying design innovation actions to gradually create an innovation culture which optimises the cultivation of innovation in the business environment.

Figure 7.5: Design innovation benefit wheel for work culture/environment improvement (design innovation framework detail)

7.2.1.4 Efficient process development

Process in this section refers to both the technical production process and the business operational process in innovative manufacturing. Design innovation also influences efficiency and optimisation in this area. The research recommends consideration of design innovation characteristics to influence the process, including: (i) *technology utilisation:*

scouting for new or appropriate technologies both in and outside the company to increase production efficiency and reduce R&D risk, (ii) use of *computer aided design (CAD)* and subsequent computer aided manufacturing (CAM) to increase process efficiency and accuracy, (iii) platform-sharing and design for better assembly while solving technical problems through *technical design*, (iv) *feasibility testing (prototyping)* to identify user preference and manufacturability early in the process to increase production efficiency, (v) *external collaboration* involving the users/clients to minimise customer rejection while increasing efficiency in personalisation (bespoke products/services), (vi) encouraging idea-sharing through *internal collaboration* across departments to identify unforeseen areas of inefficiency in production process by visualising *captured knowledge and transferring* it to appropriate areas to be improved, (vii) optimising production/assembly flow and providing flexible work-space to maximise efficiency in the *physical work environment*, (viii) prioritising innovation and use design-led business problem-solving by *top-level management* to focus optimum areas to *invest* to enhance product/service development process, and (ix) creating or improving the *business model* by using design-led tools to provide a holistic overview to identify problems/opportunities in the business operation to be optimised. The indirect influence of design innovation for efficient process development is also found in the *quality improvement* process while developing innovative products/services, particularly when designing for effective assembly to increase production efficiency. The influences of design innovation characteristics on efficient process development are shown in Figure 7.6.

Efficient process is vital for the growth of manufacturing companies, and is often seen in lean manufacturing (Katayama and Bennett, 1999, Narasimhana et al., 2006, Wilson, 2010) and just-in-time (JIT) theories (Shah and Ward, 2003). The design innovation influence on the process closely follows those theories' principles of optimisation and efficiency, but it also acts as a medium to identify areas which can be improved through holistic and empathic investigation into the production process. It also uses collaborations to bring together external and internal ideas from both experts and non-experts (from other departments) to help identify further areas for optimisation, mainly for production but also for the business operation. Developing efficient processes can optimise the business environment especially in manufacturing companies where production is a vital part of process innovation. The research therefore also recommends using design innovation in conjunction with manufacturing oriented process management principles such as lean manufacturing, to further enhance the efficiency of the process.

Figure 7.6: Design innovation benefit wheel for efficient process development (design innovation framework detail)

7.2.1.5 Clear communication

The research found that the design innovation characteristics can also enable clear communication. The recommendation derived from these characteristics is the consideration of: (i) using *CAD* to better visualise the concept by digitising ideas, (ii) designing *aesthetics* to communicate quality and brand message, (iii) *product/service value promotion* through visual and other appropriate means by understanding target audiences, (iv) using *graphics/websites* to create intuitive graphic interface, engaging websites and attractive promotional materials which clearly communicate a consistent brand message, (v) articulating an understanding of *user and market needs/demands* to the internal collaborators, (vi) conveying brand value internally by creating an engaging physical work environment, (vii) identifying key *values and vision of the company* with participation from employees and top-level management, and delivering a clear message both internally and externally, (viii) identifying, emphasising and focusing on the *USP*, and (ix) clearly communicating the business model to the stakeholders with a holistic overview to identify improvement areas. Design innovation also indirectly influences clearer communication when: (i) developing innovative products/services - identifying the *functional and/or usability* needs by understanding and predicting user behaviour and the customer journey- where this understanding helps create the best channel and method of communication, and (ii) encouraging extensive collaboration with *top-level management*.

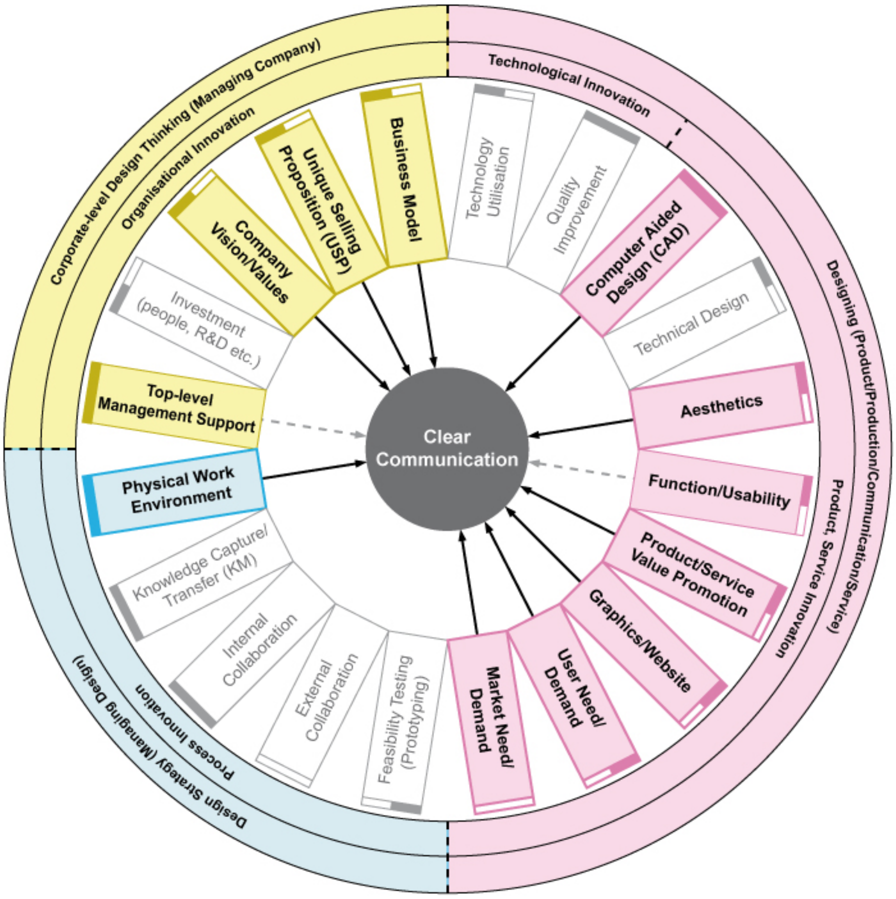


Figure 7.7: Design innovation benefit wheel for clear communication (design innovation framework detail)

Design innovation influences can enhance clear communication both technically and strategically (Figure 7.7). It includes identifying the target audience, choosing appropriate means to communicate effectively, designing communication materials, and helping the company identify appropriate and representative messages (vision, values, quality, etc.) to its audiences. This is closely linked with company branding (Mozota, 2003) where the audience can be both internal (employees) and external (users/customers and prospective users/customers). However, the research uses the term ‘communication’ rather than ‘branding’ because branding, like design, has various areas (requiring further in-depth study) which can lead to confusion among manufacturing companies, as mentioned by several design innovation experts. The research found that internal communication is essential for enhancing company employee loyalty and ownership, resulting in better commitment in developing and producing/delivering quality products/services. External communications are also crucial to successful commercialisation, to improve brand value and loyalty. The research therefore recommends the consideration of the design innovation characteristics identified to influence clear communication, to maximise innovative manufacturing companies’ internal and external branding.

7.2.1.6 Innovative product/service development

Manufacturing companies’ ultimate goal is to produce commercially successful products/services. The research also noted that most design innovation actions are geared towards innovative product/service development. Fourteen out of twenty design innovation characteristics were found to directly influence the development of innovative products/services. The research therefore recommends that manufacturing companies and design consultancies consider these characteristics including: (i) *technology utilisation* to design technologically advanced products, (ii) *quality improvement* by designing simple products which are easy to produce and service/maintain, to technically and aesthetically meet quality demands, (iii) identifying functional and ergonomic needs by understanding user behaviour, the customer journey and their expectations in *function/usability* and designing products which are functional (both in the manufacturing process and its artefacts) by using *technical design*, (iv) communicating quality and lead trends and optimising functions with product *aesthetics*, (v) using *graphics* to create an intuitive interface for products/services, (vi) identifying, forecasting and prioritising *user and market needs/demands* and adapting promptly to a changing market, (vii) using frequent *feasibility testing (prototyping)* to minimise product or service failure, (viii) planning and managing *internal and external collaborations* to obtain implicit knowledge and user insight, interpreting them into useful information, while increasing internal and external brand loyalty, (ix) appropriate *investment* in design resources and expertise to increase quality and efficiently develop products/services, (x) identifying, emphasising and focusing resources on the *USP* required for products/services, and (xi) using design-led tools to identify new sales channels and customer touchpoints to make/develop a *business model* with an efficient value chain. *Top-level management support* has indirect influence through support in identifying problems/ opportunities and developing efficient processes leading to developing innovative products/services.

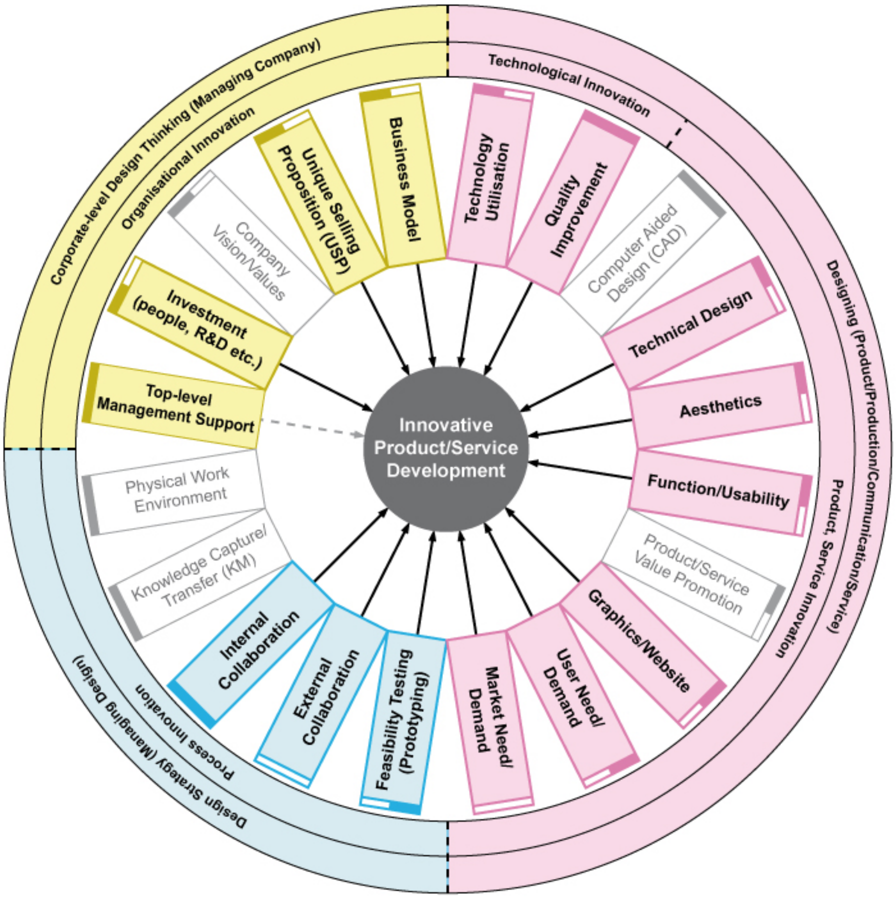


Figure 7.8: Design innovation benefit wheel for clear communication (design innovation framework detail)

Developing innovative products/services involves design at all levels of business (Cooper and Press, 1995, Rassam, 1995, Inns, 2002, Mozota, 2003, Brown, 2009, Topalian, 2013). The range of design innovation characteristics identified as influencing development clearly demonstrates this (Figure 7.8). This is the area where design is most likely to be found in innovative manufacturing companies because it includes technical design and many conventional 'designing' elements such as aesthetics and graphics/websites.

However, the research also found that collaboration, investment, the business model and user and market understanding have a direct influence on ‘innovative product/service development’. It is therefore recommended that innovative manufacturing companies consider using design innovation more broadly to increase product/service and process innovation, in turn increasing successful commercialisation.

7.2.2 Main goals of design innovation

Design innovation’s main goals were synthesised with a selective coding process. They represent the further categorisation of the design innovation characteristics, the three primary benefits of which for innovative manufacturing companies are: (i) clear idea generation, (ii) optimising the business environment, and (iii) successful commercialisation. The literatures also identified these as essential for cultivating innovation in companies (Teece, 1999, Kelly, 2001, Tidd et al., 2005, von Stamm, 2008, Mootee, 2013), so they are the three areas innovative manufacturing companies should endeavour to increase, to enhance their innovativeness.

Creative idea generation

The research identified the main source of creative idea generation as ‘extensive collaboration’ and ‘problem/opportunity identification’. Design innovation benefits encourage and spark creative idea generation by using co-creation methods to enable collaboration across the whole company (interdepartmental and cross-positional) and with customers and external organisations to maximise cross-pollination. Its empathic research of the users and a holistic approach to market and technology research help create/optimise sales channels, resulting in a new/improved business model. Although creative idea generation is used across different functions of innovative manufacturing companies, its main contribution is improving product/service and organisational innovations.

Optimising the business environment

Design innovation enables effective use of resources, including materials (reduced waste, maximised material utilisation), processes (modular system of product ranges), time (reduced product development and production lead time), productivity (a better work environment), knowledge (transfer of tacit knowledge), and investment (where it is most needed) to optimise business performance. Optimisation stems from design innovation benefits found in 'work culture/environment improvement' and 'efficient process development'. Improving these areas through design innovation also contributes to improving process and organisational innovations.

Successful commercialisation

Design innovation characteristics are determined by the nature of design innovation actions and their effects. The effects almost always help the company achieve successful commercialisation of products/services. However, the immediate influences of design innovation are mainly from 'clear communication' and 'innovative product/service development'. These benefits lead to successful commercialisation by creating aesthetically and functionally desirable high-quality products/services which are intuitive to use and easily manufactured. Their values and unique qualities are effectively communicated through graphics on the products and packages and promoted using appropriate channels for target customers. The process of creating successful commercialisation therefore also entails improvements in product/service and process innovation.

7.2.3 Construction of the framework

A framework used in qualitative research provides diagrammatic representation of a theory or concept, to explain the relations and the phenomenon of the research (Robson, 2011). This research adopts grounded theory (see Chapter 3), an inductive method where theory is generated from the data (Corbin and Strauss, 2008), so the framework is constructed after analysing the data (see Figure 7.9) obtained from the expert interviews. The design innovation framework provides a descriptive diagram of design innovation benefits in relation to three key goals and contributions to various areas of innovation. The three goals of design innovation are placed at the centre of the framework, with overlapping areas showing where contributions to innovation occur most strongly. Six design innovation benefits are placed on the outside of the three key goals with arrows towards the three key goals showing the main benefits. It is important to note here that these arrows do not represent exclusive benefits, rather, show most likely categorisation of the benefits of design innovation derived from the qualitative analysis.

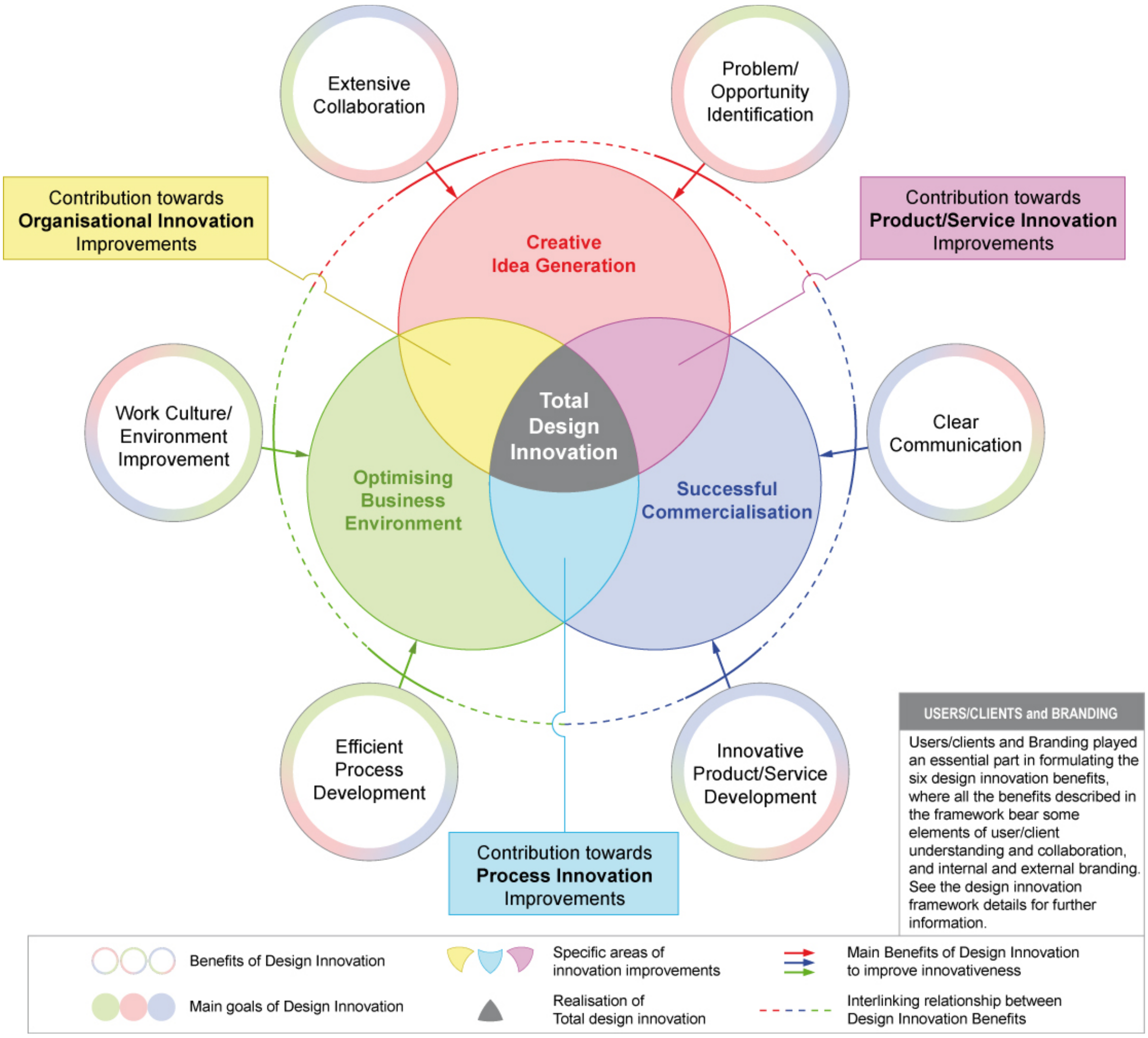


Figure 7.9: Design innovation framework for innovative manufacturing in the UK

The framework here is finalised after evaluating the ‘beta’ version (Appendix G) with the evaluation experts (Section7.4.1 and 7.5.1). It contains essential relationships identified from the research, as explained in the previous sections. Design innovation’s contribution to product/service, process and organisational innovation is shown in the intersection of three main goals as mentioned earlier. If the six benefits of design innovation are considered as inputs, then their contributions can be seen as outputs towards improving innovativeness. The research has also identified that the effects of design innovation characteristics comes from various areas of design innovation spectrum. This is most apparent in the ‘creative idea generation’ where ‘problem/opportunity identification’ and ‘extensive collaboration’ includes number of design innovation characteristics from ‘design strategy for process innovation’ areas of design innovation spectrum. This is a good example of dynamic relationship between design innovation input and innovation output where, in order to improve particular area of innovation (e.g. product/service innovation), design innovation input holistically considers other areas of innovation (e.g. process and organisational innovation as well as the product/service innovation). Therefore in the centre, the intersection which is the common denominator of all design innovation is labelled the ‘Total design innovation’ which represents the space where all benefits and subsequent characteristics of design innovation are practised similar to that of Total design and Total innovation. It is rare to find innovative manufacturing companies practicing the total design innovation because of its comprehensiveness, and some companies may not require certain elements of the design innovation characteristics because of the nature of their business. However, innovative manufacturing companies are recommended to aim to achieve total design innovation, because that process itself enhances product/service, process and organisational innovation.

7.3 Design innovation framework implementation

Every company has different problems with varying priorities and circumstances, so there is no universal solution for generating, developing and disseminating innovation (Hansen and Birkinshaw, 2007). Similarly, innovative manufacturing companies with different levels of design innovation adaptation or maturity cannot adopt the same areas of the design innovation framework. It is therefore difficult to generalise the implementation guideline for the design innovation framework which fits all situations. This is precisely why the framework must be comprehensive, to provide options to manufacturing companies to select and prioritise the areas requiring immediate attention, in order to take steps towards total design innovation practice. The research addresses this issue using the scenario method to provide three common situations to recommend how the design innovation framework can be implemented. A synthesis of strategic and innovation management processes produced a recommended design innovation implementation process. The process requires companies to understand the business situation where problems and/or opportunities are realised, and a willingness to use the framework to help improve the aspect of their innovativeness which was identified as important in implementing any design innovation activities/processes (Section 6.2.1.6). A design innovation matrix was also developed to assess the company's maturity in both design and innovation whilst running a business environment scan.

7.3.1 Implementation process

The design innovation framework suggests a comprehensive area of implementation in order to enhance innovativeness by adopting or improving design innovation characteristics according to an individual company's situation or strategy. As the design innovation phenomenon is inevitably complex, made up with complex array of actions and consequences, especially for the non-design professionals and manufacturing companies with a limited view of 'design' in their company. The research addresses this issue by simplifying the complexity using the framework to show concisely the six areas of design innovation benefits in relation to three main goals of design innovation which can easily be accepted by manufacturing companies. However, the researcher recognises that this simplification can make using the framework difficult to start and manage. The varying situations and strategies of individual manufacturing companies present implementation challenging, as different companies will require different areas of focus to effectively increase their innovativeness. A generic implementation process for the design innovation framework is therefore recommended, a constant variable within complex variables in order to provide stability for the framework implementation. The process itself is a hybrid of strategic management processes (Peter, 1993, Wheelen and Hunger, 2002), design thinking processes (Brown, 2009, Liedtka and Ogilvie, 2011) and innovation management/audit processes (Tuominen et al., 1999, von Stamm, 2003, PWC, 2013a). The generic process of design innovation framework implementation is suggested in Table 7.2.

The process includes acknowledgement of the initial problem/opportunity, which is not found in any of the management, design and innovation processes. However, as already briefly mentioned, the research found that - as emphasised by both design innovation and manufacturing experts - a crucial factor for implementing design innovation in a company is recognition of a problem or opportunity by top-level management. Furthermore, the emphasis of the process can be on prioritisation of specific areas of immediate improvement as the research also noticed manufacturing companies' reluctance to allocate resources (financial/staff time) to developing design innovation (see Chapter 4). One way suggested by the design innovation experts is to start with small manageable projects to show the value of design for that particular company, then once the company (top-level managers) recognises the value for further investment, proceed to the next step.

Table 7.2: Design innovation framework implementation process

Process	Description
1. Acknowledgement of Problem/Opportunity	Business problems such as decreasing sales and increasing competition, stale business, or opportunities through new technology development are acknowledged.
2. Business Environment Scanning	Using strategic tools familiar to the business such as SWOT, PESTEL, Balanced Scorecard, Boston Matrix, etc., to understand both external and internal business environments. The external environment includes social, economic and political forces, market/industry analysis, and the internal environment includes company structure (chain of command), culture (beliefs, expectations, values) and resources (assets, skills, competencies, knowledge). Understand the position of the company and its products/services in the current market. Prioritise the core area to develop to maximise the company's strengths and reduce weaknesses.
3. Review Mission and Vision Statements	Identify, and revise if necessary, the reason for the company's existence and values it manifests both internally and externally.
4. Benchmarking	Use tools such as Performance Profiling to assist in setting company priorities. Assess the competitor or the company's own desirable performance level to set a target. Identify the company's current performance levels in the same categories to identify the weakest areas to be prioritised. Assess the performance level of best practice in the sector (or the company's own desired level) using the six benefits of design innovation.
5. Identify Design Innovation Characteristics to Develop	Using the design innovation framework, identify the priority characteristics and subsequent design innovation actions to be considered in creating a development programme.
6. Create Programme and Allocate Budget	Create programmes to deliver the outcome, including timing responsibilities and cost to achieve the target.
7. Evaluate Outcome	Measure the actual outcome of the programmes against objectives, reviewing and amending as necessary.

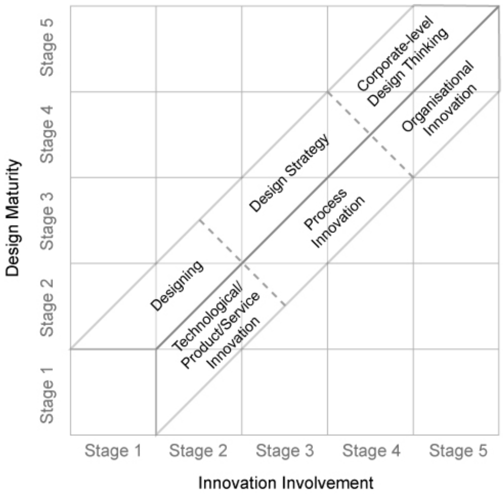
Moving from step 7 to 4: Further development in the Design Innovation Framework for Total design innovation

It is thus essential to address the company's priorities (whether survival or growth) with design innovation, rather than have a set of preordained standardised steps to force design innovation actions in the company. Furthermore, due to the complex nature of design innovation, it is recommended to acquire a design innovation expert assistant to utilise the full potential of design in enhancing innovativeness and subsequent competitiveness and growth for the innovative manufacturing companies.

7.3.2 Design innovation matrix

The level of design maturity and innovation involvement are important indicators to consider when implementing and prioritising areas of the design innovation framework - not as an audit of capabilities, rather as an overview of the situation of the company's use and implementation of design and innovation. The design maturity level is adapted from the Danish Design Centre design ladder (DDC, 2003) which is also adopted by the SEE project (SEE, 2010), DME Awards in assessing design management capabilities (Kootstra, 2009) and Storvang et al, putting the design capacity framework in the Danish context (Storvang et al., 2014). Drawing on previous and current usage of the design maturity indicators (also referred to as a design ladder), in this research the maturity levels are divided into five stages: (i) no design - design plays no role in product/service development, (ii) design as styling - design is only relevant in terms of style, (iii) design as process - design is integral to the development process, (iv) design as strategy - design is a key strategic means of encouraging, and (v) design as culture - design thinking practiced at all levels of the business. After considering design maturity, the innovation involvement by Bessant and Tidd (2007) is adopted to gauge the level of innovation maturity, similar to the design ladder concept. The adopted stages of innovation involvement are: (i) natural/background - little or no systematic innovative involvement, (ii) structured - some systematic innovative involvement in parts of the organisation, (iii) goal-oriented - aligning strategic goals with systematic innovation, (iv) proactive/ empowered - internally initiated, open-ended learning innovative involvement, and (v) best practice - innovative involvement as the dominant culture. The maturity level indicators for both design and innovation were used to form the design innovation matrix, with the design innovation spectrum showing the maturity of both design and innovation in the company (Figure 7.10).

The design innovation spectrum is added to the matrix to provide relevance to the design innovation framework. It also provides a balanced view between design and innovation where a company's optimum position will be within the spectrum which indicates using design to encourage greater company involvement in innovation.



	Design Maturity	Innovation Involvement
Stage 1	No Design- Design plays no role in product/service development	Little or no systematic innovative involvement
Stage 2	Design as Styling- Design is only relevant in terms of style	Some systematic innovative involvement in parts of organisation
Stage 3	Design as Process- Design is integral to the development process	Aligning strategic goals with systematic innovation
Stage 4	Design as Strategy- Design is a key strategic means of encouraging innovation	Internally initiated, open-ended learning innovative involvement
Stage 5	Design as Culture- Design thinking practiced in all levels of business	Innovative involvement as a dominant culture

Figure 7.10: Design innovation matrix (left) with a description of each stage for design and innovation (right)

7.3.3 Scenarios

Scenarios are often used in strategic management practice as a tool to identify signposts and strategic foresights which lead to important changes for a company to thrive on uncertainty (Toner et al., 2015). It is also used by design professionals to provide real-life context to concepts, and to foresee possible future situations for creating appropriate solutions (Kumar, 2013). This research also adopts the scenario to provide a context for using the design innovation framework and its implementation, as every manufacturing company has different problems with varying priorities and circumstances and different levels of design innovation adaptation or maturity. The scenario must be pertinent, coherent, and plausible for it to hold any value in business (Durance and Godet, 2010), so the scenarios for this research were created using the forty-six innovative manufacturing company case studies, searching for common situations likely to initiate design innovation framework implementation. The research found three situations which cover the majority of companies: (i) the company with decreasing market share and customers, (ii) the established company wanting to expand its business, and (iii) the entrepreneurial technology start-up company. The three situations are similar to areas of support by the Design Council’s Designing Demand programme (DC, 2010) which adds plausibility of the scenarios. Three innovative manufacturing company scenarios were created using these common situations, by using the characteristics of companies found in the case study and the examples suggested by design innovation and manufacturing experts during in-depth interviews.

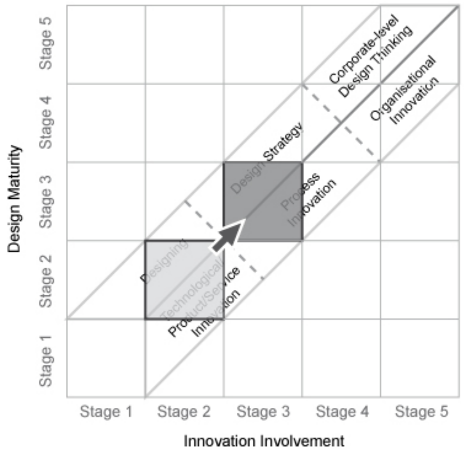
Design Innovation Framework Implementation

Scenario 1: ‘Company A’ with decreasing market share and customers - Part 1

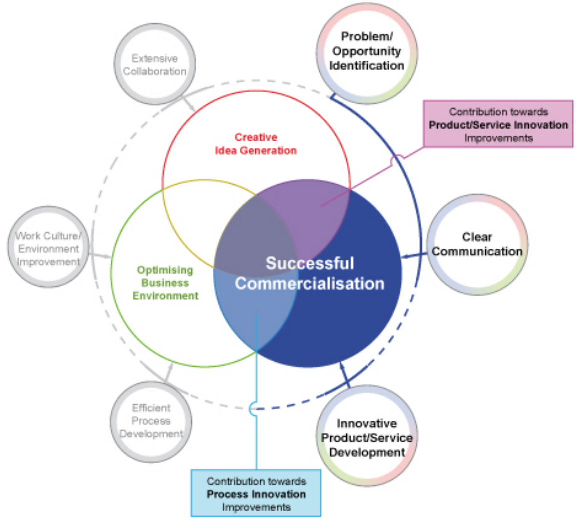
Background

Company A is a manufacturing company which supplies temperature measurement devices for the oil and gas industry to ensure pipelines maintain a constant temperature. The company was founded by a group of researchers with an engineering background when they developed a new technology which can be used in extreme environments with great accuracy and can be produced at relatively low cost. The first product was launched fifteen years ago. The product has been improved over the years for greater accuracy, but competition has increased, especially from overseas companies providing a similar product at lower prices. With declining product sales, the company wants to survive in the market.

Design Innovation Matrix for Company A



Design Innovation Framework with strategic priority in Succesful commercialisation



Design Innovation Framework Implementation Process (Continued on next page)

Acknowledgement of Problem/Opportunity	Business Environment Scanning	Mission and Vision Statements	Benchmarking
The founders and top-level managers are aware of falling market share and sales. However, the recent introduction of less sophisticated but cheaper products made by companies in Italy and Brazil have become such a threat that they are starting to lose even the regular clients who are stringently cutting costs because of the global oil price decrease. In an annual strategic meeting, they all agreed the need to increase innovativeness to compete in the market, and decided to hire a design innovation consultancy as recommended by the Business Growth Service (former MAS). The consultancy uses the Design Innovation Framework to assess, advise and deliver better innovation for the company.	Company A's main product is in the late stage of its lifecycle, adoption and sales both declining. The consultants ran a series of workshop sessions with top-level managers and key employees to critically evaluate the company's situation and position using both traditional tools familiar to the stakeholders (SWOT analysis and the Boston Matrix) and some design-led tools (Lovemark and the Design Innovation Matrix). The priority was initially set as 'successful commercialisation' in the Design Innovation Framework, as the most urgent area was survival in the market. The company's core competence was identified as its unique patented technology which accurately measures temperatures at a higher pressure than any of its competitors.	The company had no mission or vision statements, but top-level managers realised the importance of such statements to address company values to both employees and customers. After the workshop with consultants, top-level managers and participating employees from different departments, they created mission and vision statements which represent the company's core competence and values.	The leading company in a similar sector to Company A was identified to benchmark its performance. The performance of six areas of design innovation benefits were identified and compared with Company A's self-assessment. Problem/opportunity identification, clear communication, innovative product/service development, and efficient process developments showed the biggest difference in performance. These areas were therefore chosen for further development and the company's strategic priority was confirmed as 'successful commercialisation' to increase product/service and process innovativeness.

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Figure 7.11: Example of scenario presented in the design innovation framework booklet (first page for Scenario 1)

Design Innovation Framework Implementation

Scenario 1: ‘Company A’ with decreasing market share and customers - Part 2

Detailed charateristics (in grey) to fulfill strategic priorities and to encourage successful commercialisation for the Comany A

Design Innovation Framework Implementation Process (Continued from previous page)

Identify Design Innovation Characteristics and its Elements to Develop	Create Programme and Allocate Budget	Evaluate Outcome
Please see next page for details	The design innovation consultancy has developed a series of programmes for using design to develop the appropriate areas identified as a priority. Not all programmes were executed to keep the development within the budget. The final outcome is a series of products to complement the existing product. An emphasis was advocated on delivering a brand image of quality and technological advancement, using aesthetics and communications for the new products. The products are positioned at the upper end of the market, with expansion to aerospace and defence to increase exports.	Programmes developed using the design innovation framework have been mostly successful. The strategic targets to survive in the market with increasing competition have been satisfied with increased competitiveness by using design innovation elements. Furthermore, a new overseas market has provided the company with much needed cash-flow to invest in other areas of design innovation benefit (creative idea generation) to increase the company's innovativeness further towards Total design innovation.

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Figure 7.12: Example of scenario presented in the design innovation framework booklet (second page for Scenario 1)

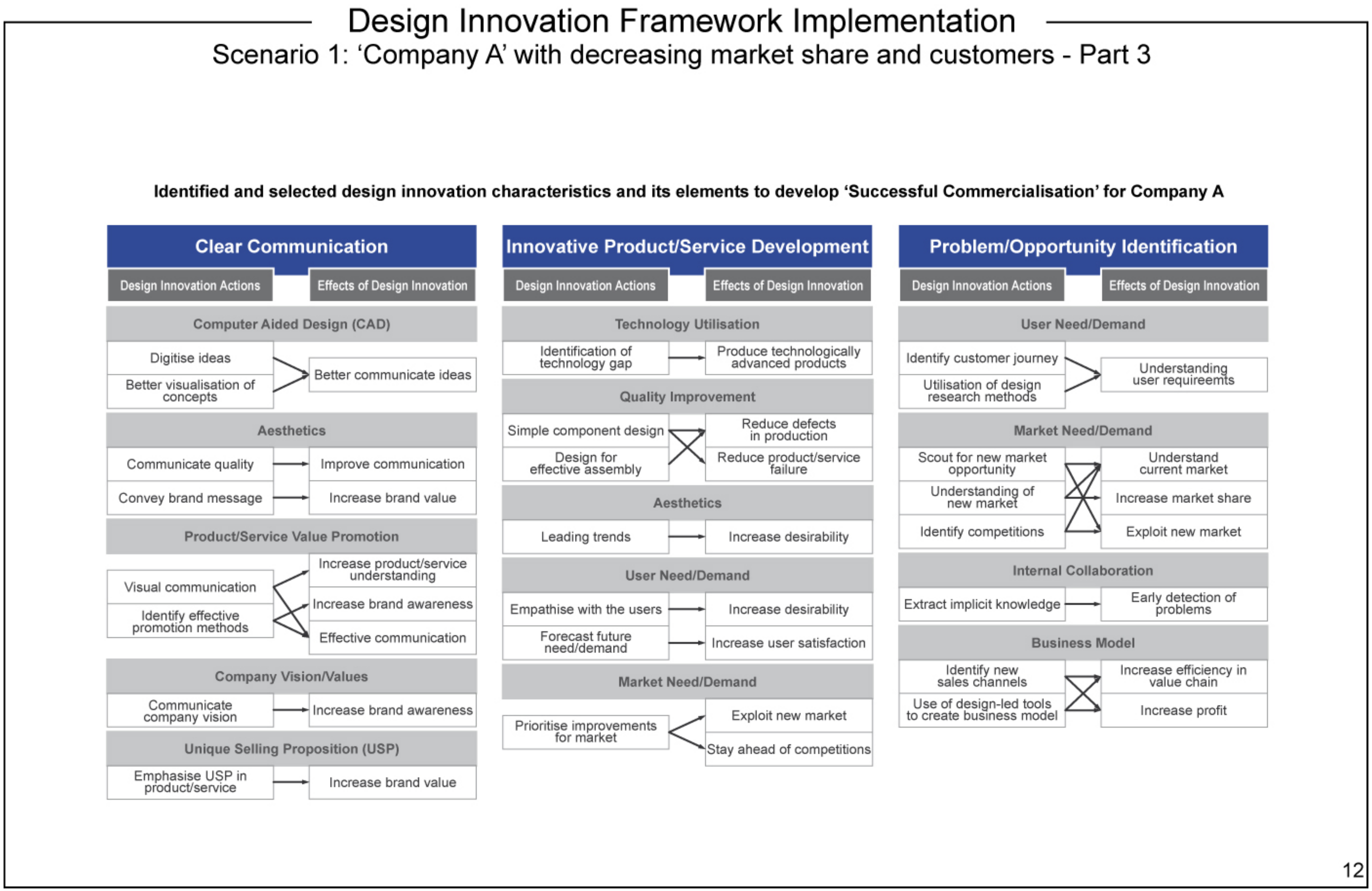

Figure 7.13: Example of scenario presented in the design innovation framework booklet (third page for Scenario 1)

The solutions to the problems faced by these innovative manufacturing companies are also derived from the case study and the design innovation and manufacturing experts which are then approved by the evaluation experts (see Section 7.4.4). The researcher recognises there may be other possible solutions because of the endless variables in the scenario situations. However, to formulate the research recommendations, the solutions focused on the design innovation framework and its implementation process. An example of the scenario presentation in the design innovation framework booklet is shown in Figure 7.11, Figure 7.12 and Figure 7.13. Full presentation of all scenarios can be seen in Appendix H.

7.3.3.1 Scenario 1: 'Company A' with decreasing market share and customers

Company A is a manufacturing company which supplies temperature measurement devices for the oil and gas industry to ensure pipelines maintain a constant temperature. The company was founded by a group of researchers with an engineering background when they developed a new technology which can be used in extreme environments with great accuracy and can be produced at relatively low cost. The first product was launched fifteen years ago. The product has been improved over the years for greater accuracy, but competition has increased, especially from overseas companies providing a similar product at lower prices. With declining product sales, the company wants to survive in the market.

Acknowledgement of problem/opportunity

The founders and top-level managers are aware of falling market share and sales. However, the recent introduction of less sophisticated but cheaper products made by companies in Italy and Brazil have become such a threat that they are starting to lose even the regular clients who are stringently cutting costs because of the global oil price decrease. In an annual strategic meeting, they all agreed the need to increase innovativeness to compete in the market, and decided to hire a design innovation consultancy as recommended by the Business Growth Service (former MAS). The consultancy uses the Design Innovation Framework to assess, advice and deliver better innovation for the company.

Business environment scanning

Company A's main product is in the late stage of its lifecycle, adoption and sales both declining. The consultants ran a series of workshop sessions with top-level managers and key employees to critically evaluate the company's situation and position using both traditional tools familiar to the stakeholders (SWOT analysis and the Boston Matrix) and some design-led tools (Lovemark and the Design Innovation Matrix) (Figure 7.14). The priority was initially set as 'successful commercialisation' in the Design Innovation Framework, as the most urgent area was survival in the market. The company's core competence was identified as its unique patented technology which accurately measures temperatures at a higher pressure than any of its competitors.

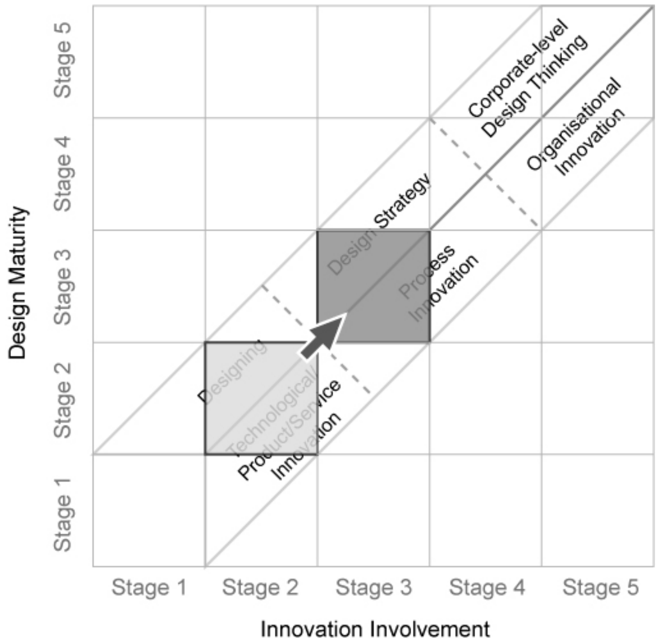

Figure 7.14: Design innovation matrix for Company A

Review mission and vision statements

The company had no mission or vision statements, but top-level managers realised the importance of such statements to address company values to both employees and customers. After the workshop with consultants, top-level managers and participating employees from different departments, they created mission and vision statements which represent the company's core competence and values.

Benchmarking

The leading company in a similar sector to Company A was identified to benchmark its performance. The performance of six areas of design innovation benefits were identified and compared with Company A's self-assessment. Problem/opportunity identification, clear communication, innovative product/ service development, and efficient process developments showed the biggest difference in performance. These areas were therefore chosen for further development and the company's strategic priority was confirmed as 'successful commercialisation' to increase product/service and process innovativeness (Figure 7.15).

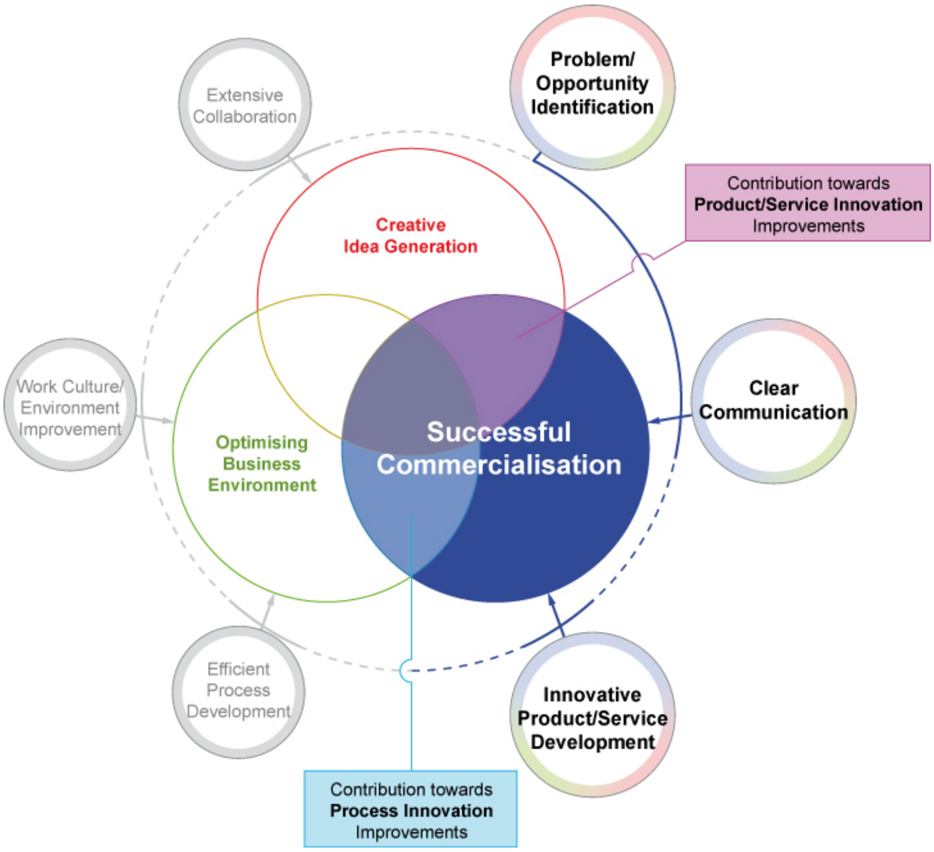

Figure 7.15: Design innovation framework with strategic priorities in successful commercialisation (Company A)

Identifying which design innovation characteristics to develop

For clear communication, design innovation characteristics including computer aided design (digitising ideas, better visualisation of concepts), aesthetics (communicate quality, convey brand message), product/service value promotion (visual communication, identify effective promotion methods), company vision/values (communicate company vision) and unique selling proposition (emphasise USP in product/service, communicate USP) were identified as priorities.

The characteristics to prioritise for innovative product/service development were, technology utilisation (identify appropriate technology gap), quality improvement (simple component design, design for effective assembly), aesthetics (leading trend), user need/demand (forecast future demand, identify opportunity for new users) and market need/demand (prioritise improvements in the market). Finally, the following were identified for improve problem/opportunity identification: user need/demand (identify the customer journey, utilisation of design research methods), market need/demand (understand the current market, scout for new markets, identify competition), internal collaboration (encourage idea-sharing, communication between stakeholders) and the business model (identify new sales channels, utilisation of design-led tools to create a business model) (Figure 7.16 and Figure 7.17).

Create a programme and allocate a budget

The design innovation consultancy has developed a series of programmes for using design to develop the appropriate areas identified as a priority. Not all programmes were executed to keep the development within the budget. The final outcome is a series of products to complement the existing product. An emphasis was advocated on delivering a brand image of quality and technological advancement, using aesthetics and communications for the new products. The products are positioned at the upper end of the market, with expansion to aerospace and defence to increase exports.

Evaluate the outcome (back to Benchmarking - further development in the design innovation framework for total design innovation)

Programmes developed using the design innovation framework have been mostly successful. The strategic targets to survive in the market with increasing competition have been satisfied with increased competitiveness by using design innovation elements. Furthermore, a new overseas market has provided the company with much needed cash-flow to invest in other areas of design innovation benefit (creative idea generation) to increase the company’s innovativeness further towards Total design innovation.

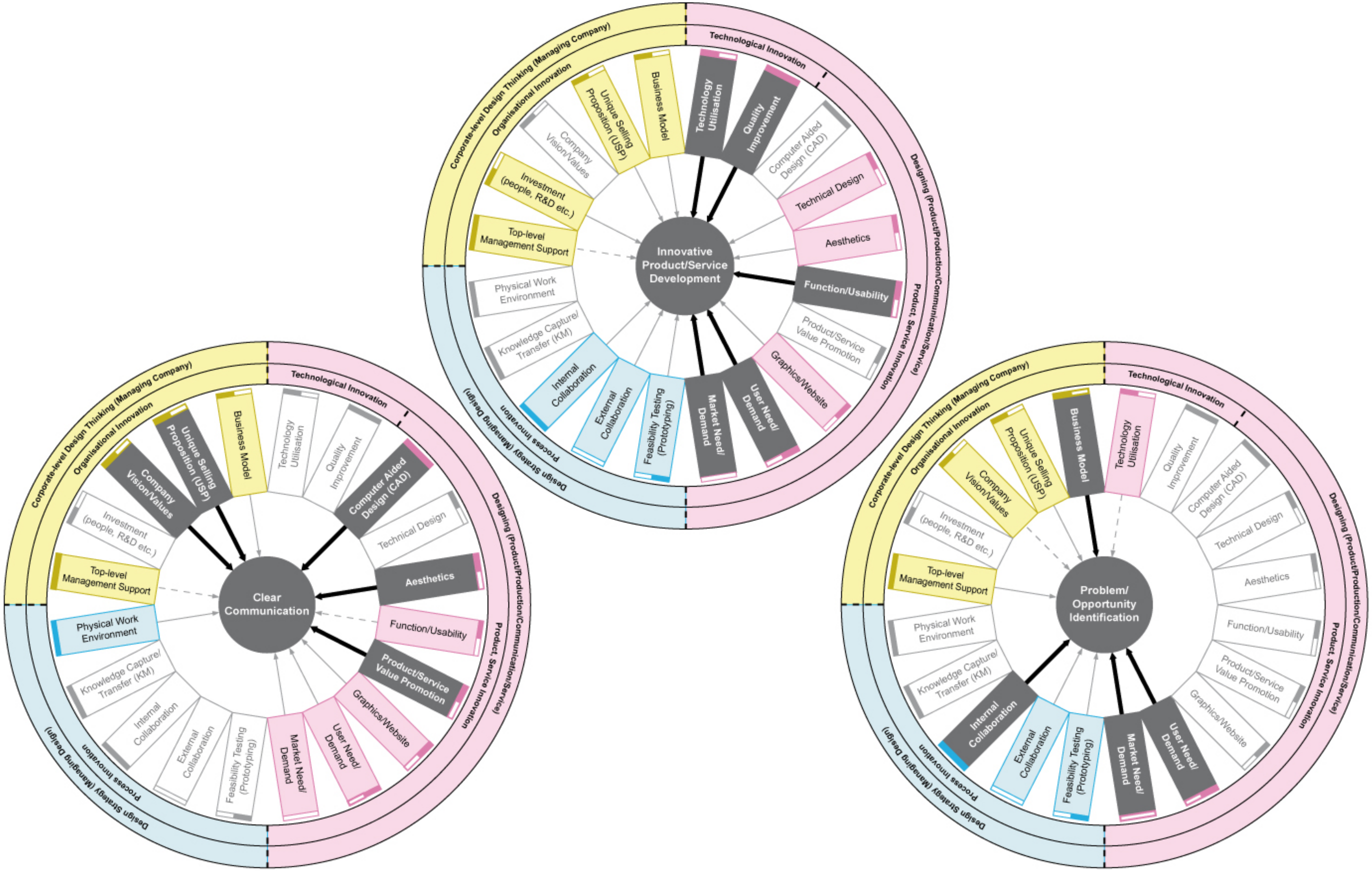

Figure 7.16: Priority areas of design innovation characteristics which need to be developed for Company A

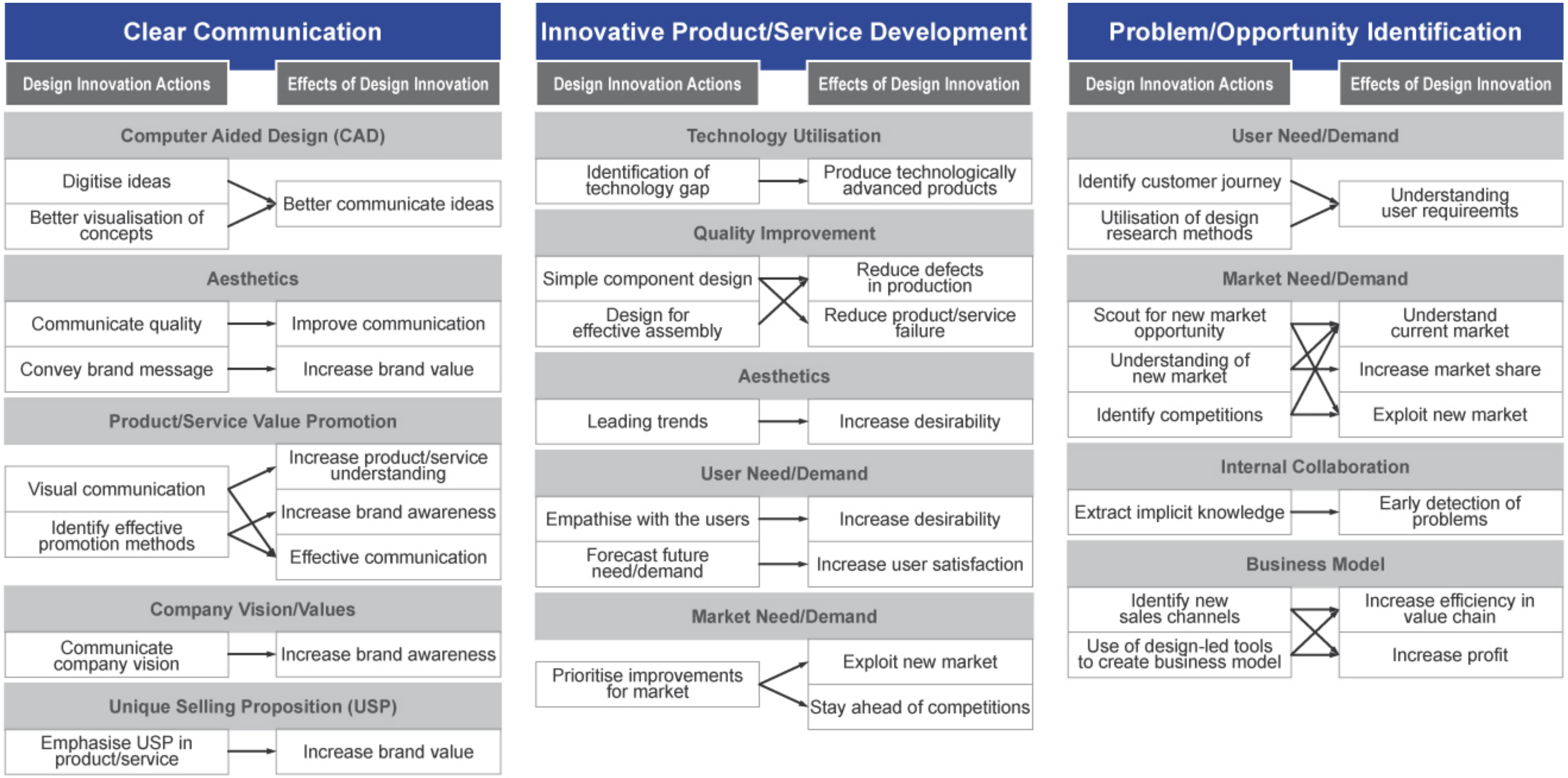

Figure 7.17: Design innovation action, effects and benefits for priority areas for Company A to ensure successful commercialisation

7.3.3.2 Scenario 2: Established 'Company B' which hopes to expand its business

Manufacturing company B has a stable list of clients with solid demand for its products and services. The company, established forty years ago, produces electrical switches for both domestic and commercial use (B2C and B2C) with eighty per cent of its sales in the EU. The company is known for its product reliability with continuing improvements to satisfy current users' demand. It is also capable of providing bespoke products in small batches and subsequent services to its clients by using a flexible manufacturing method. However, the company directors want to anticipate the fast changing market environment by increasing innovativeness in the company.

Acknowledgement of the problem/opportunity

The company has stable cash-flow and revenue, but the top-level managers agree that business has become stale both in the product offerings and in the work culture. They therefore decided to improve their innovativeness to ensure business expansion and anticipate future competition. A dedicated innovation team offers the customer new or improved products every year, but the directors agreed to use the team to develop the process and organisational innovation to increase the company's profit margins and competitiveness. The innovation team decided to use the Design Innovation Framework to diagnose and improve the company's innovativeness.

Business environment scanning

The innovation team conducted a series of interviews with employees in various departments to understand the work culture and identify areas which could be improved. They found that Company B's production process has not changed for over twenty years. A large proportion of the shop-floor employees have been with the company for over ten years, but with minimal involvement in the NPD. The design team consists of engineering designers and a product designer, but their involvement in innovation is low, which is represented in the design innovation matrix (Figure 7.18). The findings were presented in a boardroom meeting, and the directors decided to prioritise 'optimising business environment'.

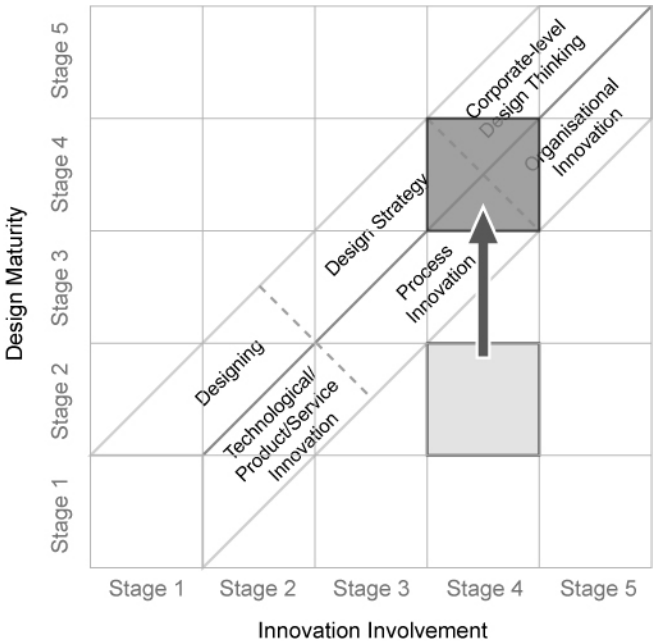

Figure 7.18: Design innovation matrix for Company B

Review mission and vision statements

The company’s mission is to provide reliable light switches which can be used everywhere from domestic homes to space stations, but the mission and vision were not communicated adequately either internally or externally. After a workshop with key employees, directors and external consultants, an additional competence of the company was established, so the mission and vision were altered to reflect the new capabilities.

Benchmarking

The innovation team also ran a workshop to understand the market situation, inviting academics in the same sector and consultants who have worked in a similar sector. They benchmarked three companies, one a well-known innovative global company, another company in a similar sector, and lastly a direct competitor with Company B. As a result of the session, the company decided to prioritise ‘efficient process development’, ‘work culture/ environment improvement’ and ‘extensive collaboration’ (Figure 7.19), led by the innovation team in the first phase of innovation development.

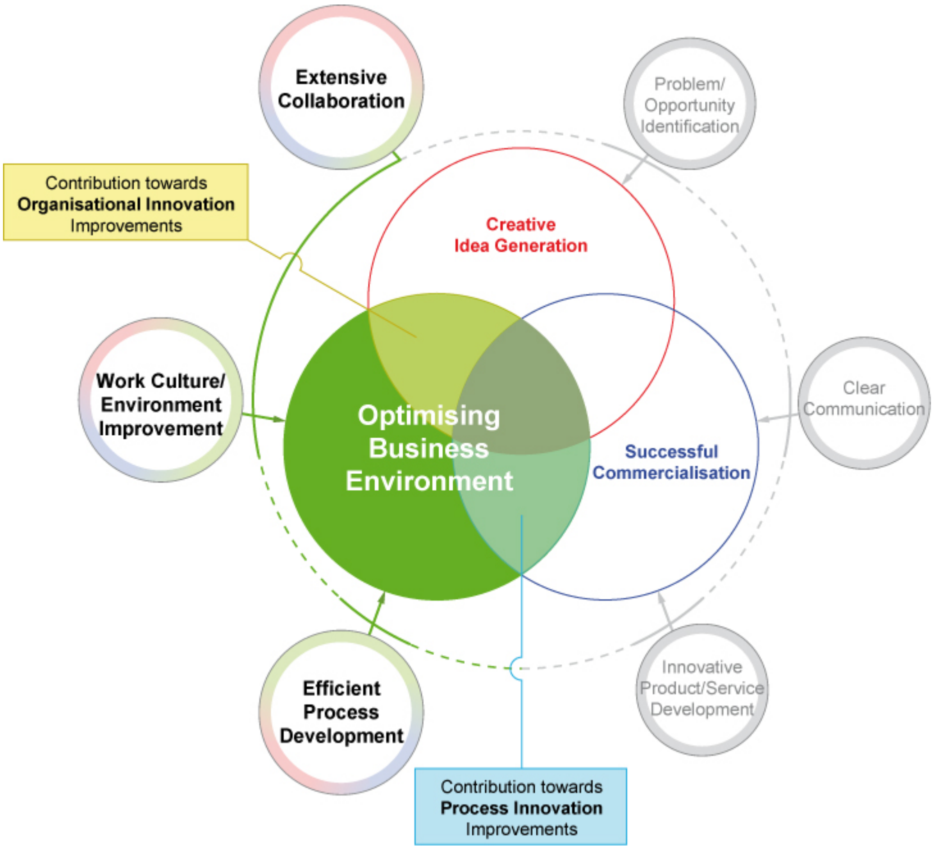

Figure 7.19: Design innovation framework with strategic priorities in optimising business environment (Company B)

Identify design innovation characteristics to develop

To enable extensive collaboration, internal collaboration (extracting implicit knowledge, communication between stakeholders, synthesis of ideas, a place for collaboration), external collaboration (involve users/clients in NPD, identify areas needed for external collaboration, interpret and mediate information, develop a programme of collaboration), top-level management support (prioritisation of innovation) were all identified as priorities for improvement. Identified priorities for work culture/environment improvement design innovation characteristics were company vision/values (create customer focused vision, identify key values, encourage employee participation), physical work environment (optimising production/assembly flow, flexible working space), internal collaboration (encourage idea-sharing, communication between shareholders) and graphics/website (consistent internal branding, clear communication). Finally, the characteristics chosen to prioritise for efficient process development were technology utilisation (identifying appropriate technology, identification of technology gap), feasibility testing (identify user preferences), knowledge capture/transfer (visualise knowledge pool, identify the expertise required in NPD, improve articulation of experiences), the physical work environment (optimise production/assembly flow, flexible working space), and the business model (identify a new sales channel, holistic overview of business model, utilisation of design-led tools to create a business model, identify problem/opportunity in the business operation) (see Figure 7.20 and Figure 7.21).

Create a programme and allocate a budget

Using the priority design innovation characteristics, briefs were created for design innovation and engineering design agencies. The objectives of the collaboration between the agencies and the innovation team are: (i) review and create a business model to increase profit, (ii) develop internal branding to improve internal company communication (iii) increase employee engagement in NPD and idea-sharing by including collaboration spaces between the shop floor and offices, and (iv) optimise the production process by utilising the latest technology to reduce wasted space and resources.

Evaluate the outcome (back to Benchmarking - further development in the design innovation framework for total design innovation)

A design innovation consultancy was hired to work with the innovation team, conducting projects to fulfil objectives (i) and (ii). Internal branding has changed the work culture significantly. Employees are much more satisfied with the work and now share ideas more frequently. Implicit knowledge of more experienced staff is now cross-pollinated in different departments. The company has started a second phase of optimising business (objectives (iii) and (iv)), initiated by collaboration among employees, led by the innovation team.

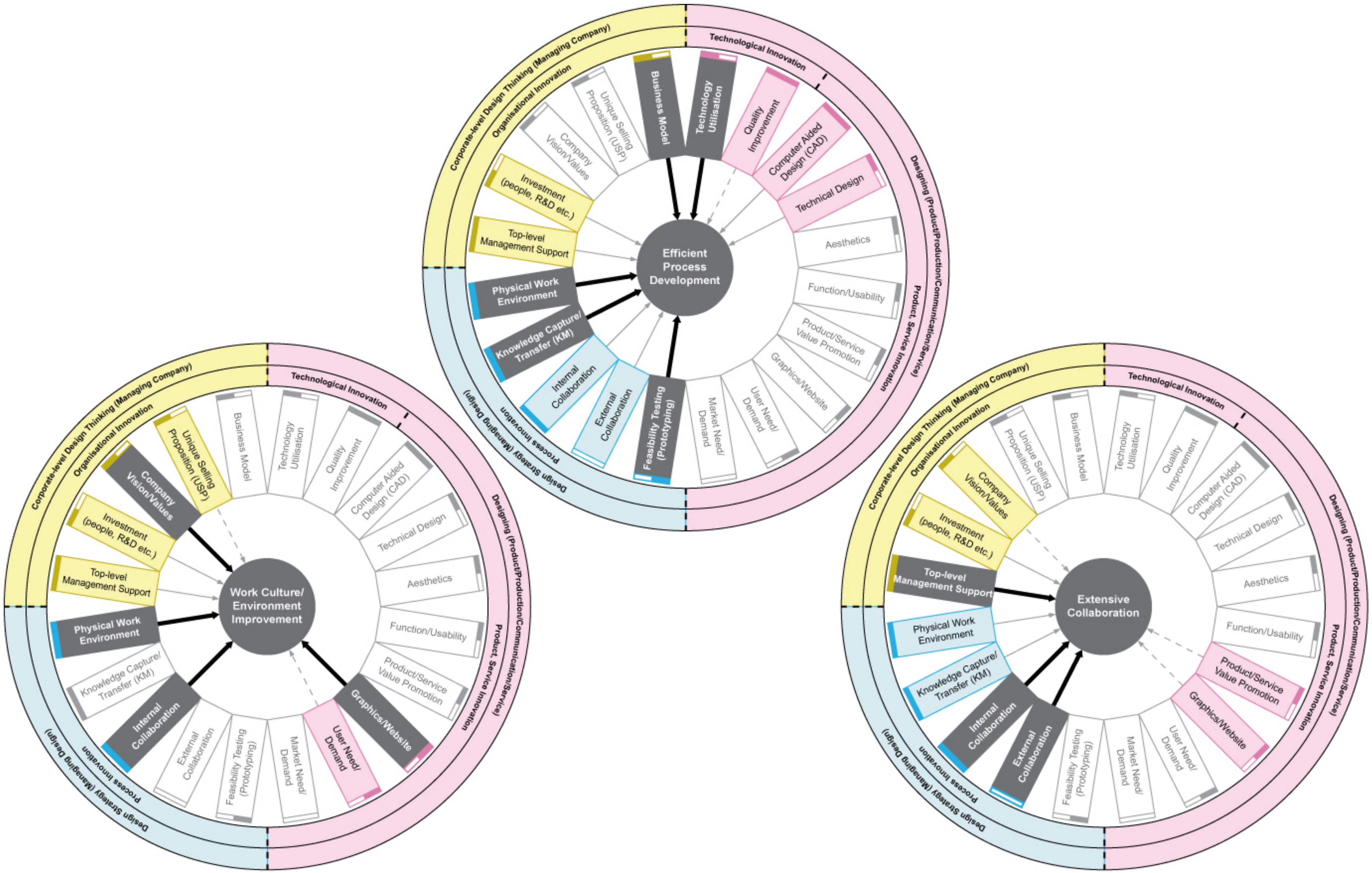

Figure 7.20: Priority areas of design innovation characteristics which need to be developed for Company B

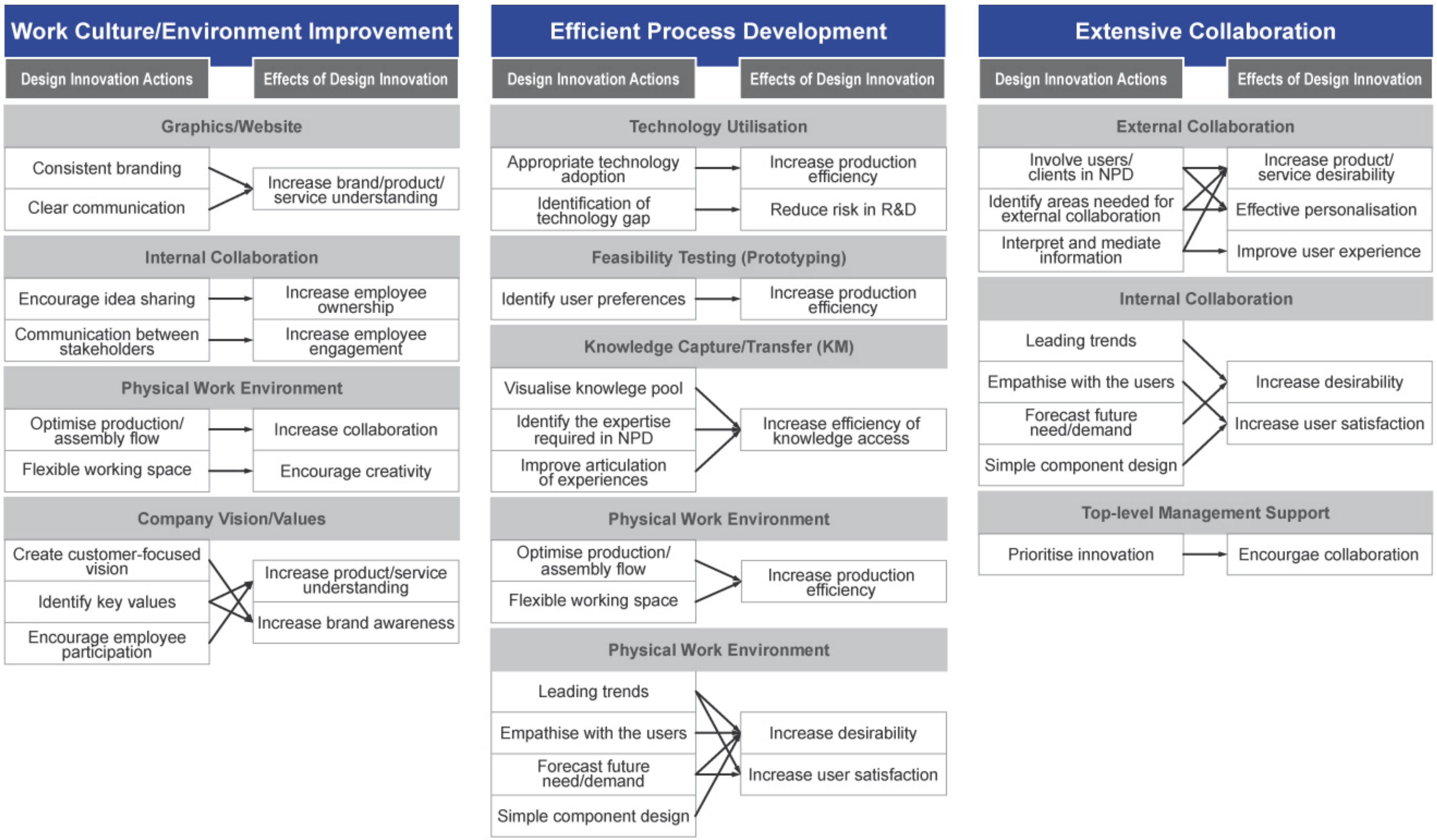

Figure 7.21: Design innovation action, effects and benefits for priority areas for Company B to optimise business environment

7.3.3.3 Scenario 3: Technology entrepreneurial start-up 'Company C'

Company C is a start-up manufacturer producing products using technology developed from a university research lab. The core technology is the ability to manipulate specially formulated aluminium alloy power to create 3D objects with high accuracy, using a self-built 3D printer. It produces bespoke parts for Formula One cars and for military application. The company has been given a government start-up grant but requires further investment to continue refining the process to become more widely available. The founders also want the company to adopt total design innovation theory in order to build an innovative business which can lead the market.

Acknowledgement of problem/opportunity

The company founders hope to build a company which excels in innovation, to find new opportunities with the existing in-house technology. As a start-up company, the company operation is very flexible in adopting new approaches but not systematic. The company now works with a university which runs a design innovation boost programme for technology start-ups. The programme uses the Design Innovation Framework to support manufacturing companies to practice Total design innovation which addresses comprehensive design innovation areas to enhance company competitiveness.

Business environment scanning

A design innovation consultant was linked with the company by the university support programme. The consultant ran a workshop with Company C founders and employees to identify the company's business environment, using brainstorming and the PESTEL tool. The consultant assessed the company on the design innovation matrix to show the current maturity of design and innovation (Figure 7.22). The workshop outcome was identifying the company's core competence, both in the technological sense and in how they create the bespoke products demanded by their clients. They also identified their lack of systematic idea generation leading to a new product, because the company only relied on fulfilling client requests to produce bespoke products. The company has therefore decided to initiate the total innovation journey with 'creative idea generation'.

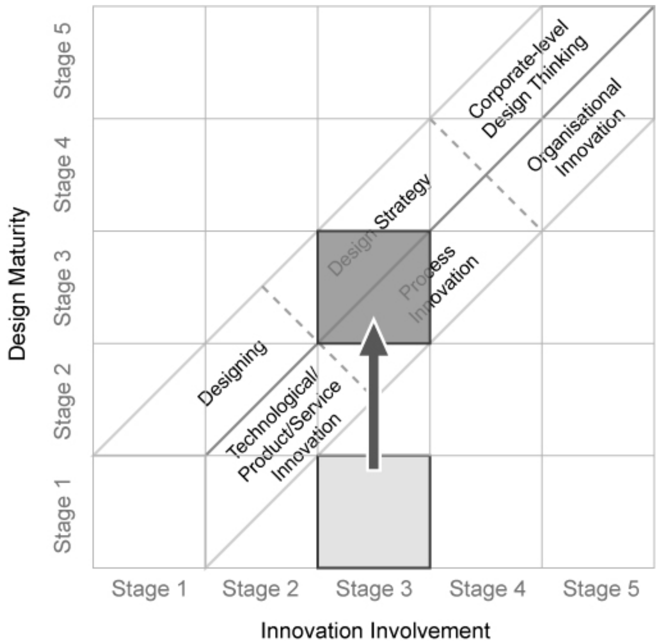

Figure 7.22: Design innovation matrix for Company C

Review the mission and vision statements

The company focus has been technology advancement, but the workshop provided new ideas and possibilities, so the founders identified a new vision for the company: to focus more on cultivating and using creativity to become more innovative in product, service, process and the organisation as a whole. The perception of design has also changed, and they are now considering hiring a design director to lead all the company's design innovation operations.

Benchmarking

A second workshop was held with the consultants and other professionals in the field similar to Company C. Before the workshop, the company founders identified several companies they wanted to benchmark. Some were multinational companies in a different sector and some were some organisations in the same sector. Initial discussions identified the performance level in the six essential benefits of design innovation. Further desk research identified priority areas for the company: 'extensive collaboration', 'problem/opportunity identification', and 'clear communication' (Figure 7.23).

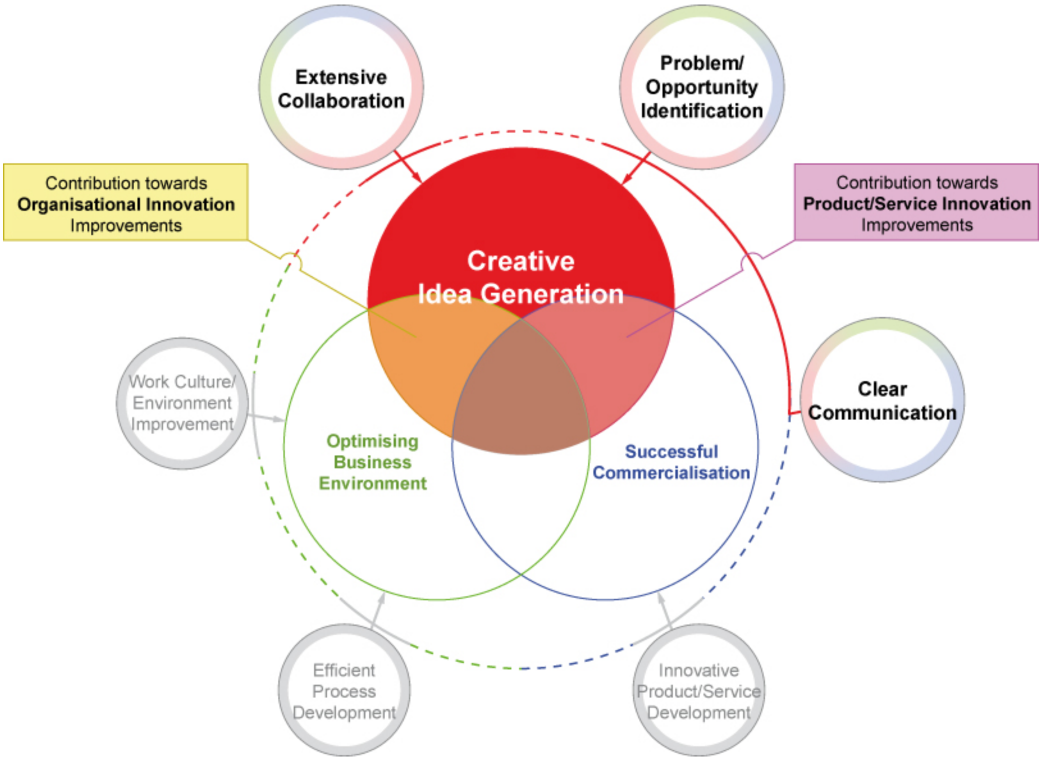

Figure 7.23: Design innovation framework with strategic priorities in creative idea generation (Company C)

Identify design innovation characteristics to develop

To enable extensive collaboration, priorities for improvement were identified: investment (investment in design expertise), physical work environment (flexible working space, space for collaboration), and external collaboration (identify areas needed for external collaboration, develop programme of collaboration). For problem/opportunity identification, design innovation characteristics including the business model (identify a new sales channel, use of design-led tools to create a business model), user need/demand (forecast future need/demand, identify opportunities for new users), and market need/demand (scout for new market opportunities, prioritise market improvements). Finally, priority characteristics identified for clear communication were aesthetics (communicate quality, convey the brand message), graphic/website (consistent branding, attractive promotional material, engaging website), company vision/value (communicate the company vision), and unique selling proposition (communicate the USP, focus resources to develop the USP) (see Figure 7.24 and Figure 7.25).

Figure 7.24: Priority areas of design innovation characteristics which need to be developed for Company C

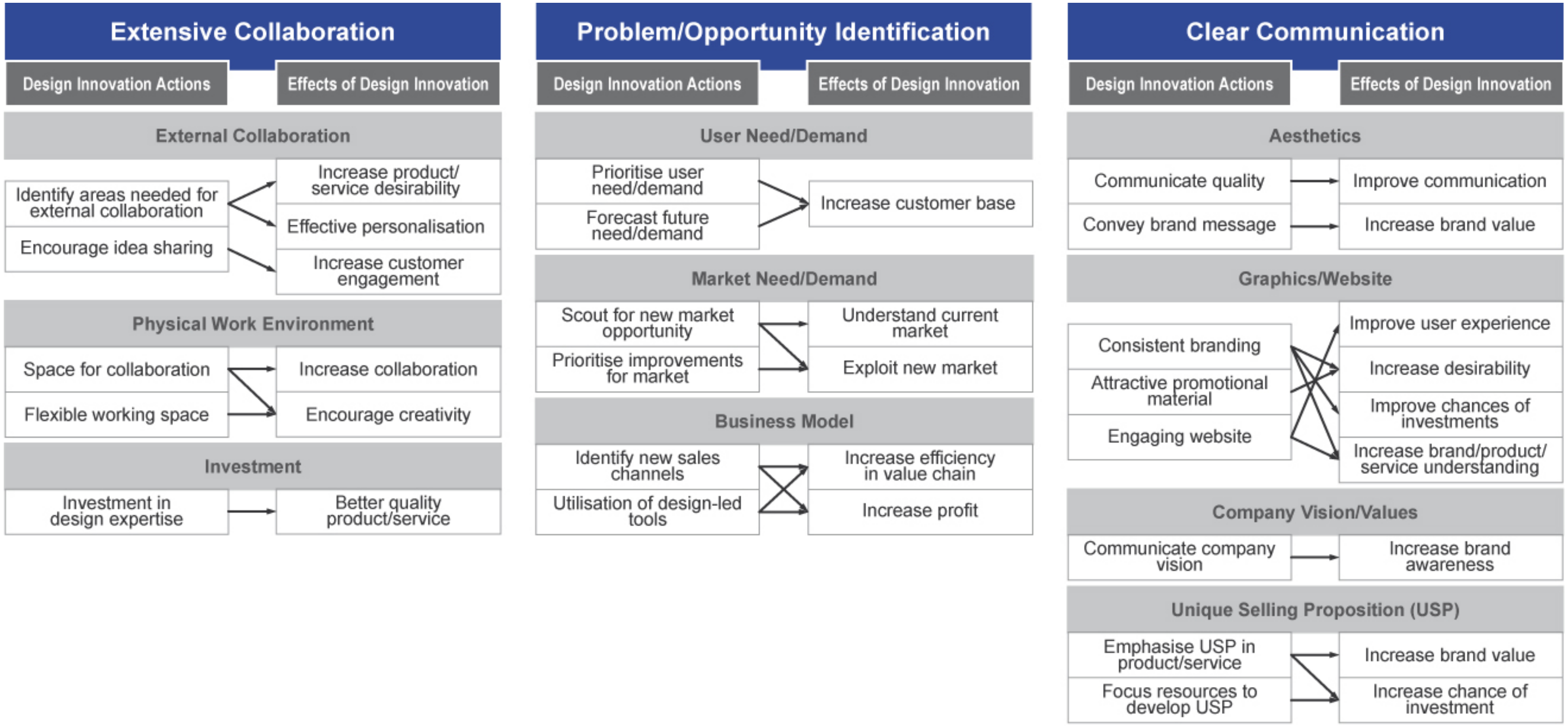

Figure 7.25: Design innovation action, effects and benefits for priority areas for Company C to enable creative idea generation

Create a programme and allocate a budget

The company, with support from the consultant, created a strategic plan to develop the priority design innovation characteristics. First they emphasised the company USP and branding and created a business model which was received well by new investors. With the investment, the company hired a new creative director to create design-led programmes in order to understand potential new users and markets and find opportunities. The company has also created set of programmes to enhance creativity in NPD and new service offerings to use its technology in a new market.

Evaluate the outcome (back to Benchmarking - further development of the design innovation framework for total design innovation)

The programmes developed through the design innovation framework and university collaboration have made the company more competent at identifying opportunities and delivering products and services which potential users would value. The immediate financial achievement through new investment has helped the company to grow its design innovation capabilities and expand into new markets by understanding the new users. The company now seeks to improve its innovativeness further by developing other design innovation characteristics, working towards becoming a total design innovation company.

7.4 Design innovation framework and implementation evaluation

The initial design innovation framework and subsequent implementation process (see Appendix G) were evaluated by experts in design innovation and manufacturing who are also prospective framework users. They included top-level managers of UK innovative manufacturing companies (n=4), senior/middle managers heading design or innovation departments (n=3), and design innovation consultants (n=3) with extensive experience of advising on design innovation at all business levels of UK innovative manufacturing companies (Section 3.3.5.4). The key issues addressed in the evaluation interviews were: (i) acceptability, (ii) potential usefulness, (iii) comprehensiveness, and (iv) usability of the framework, implementation and scenarios. The initial framework and implementation (including the scenarios) were included in a booklet designed to obtain feedback. Additional details (the design innovation spectrum, and design innovation characteristics) were also included, to explain the logic behind the framework construction. Interviewees were asked to go through the booklet and share their thoughts while the researcher asked questions relating to the key issues. Due to the time constraints of the research, the framework could not be evaluated after 'real-life' use. Therefore the experts were asked provide their opinions of the framework's potential usefulness and usability if it is applied in the 'real-life' situations.

The theories which construct the framework are derived from expert interviews. Two of the evaluation experts (interviewees EE4 and EE10) were involved in this theory-building stage. Although the framework contains more design innovation actions and effects, added by other experts, interviewees EE4 and EE10 were asked about the validity of the framework construction. Both experts regarded the framework construction process as detailed and plausible. They also recognised the complexity of analysing different opinions to formulate a theory, but broadly agreed with the results (design innovation characteristics) as a good representation of their opinions of the phenomena.

7.4.1 Design innovation framework evaluation

The design innovation framework has been well received for its acceptability, potential usefulness, comprehensiveness and ease of use. Although, the framework was sent prior to the interview, most interviewees could not allocate time to review it in detail. The introduction explaining the purpose and brief background of the framework's construction was therefore unfamiliar to most interviewees. Despite this lack of prior awareness, most of the evaluation experts understood the framework (Table 7.3).

Table 7.3: Result of evaluating design innovation framework as whole

	Manufacturing (n=4)	Design/Innovation managers (n=3)	Design/Innovation consultants (n=3)	Total number agreed (n=10)
Acceptable	EE3, (EE2)*, EE4	EE5, EE6, EE7	EE8, EE9, EE10	8 (9)*
Potentially Useful	EE1, EE3, EE4	EE5, EE6, EE7	EE8, EE9, EE10	9
Comprehensive	EE1, EE2, EE3, EE4	EE6, EE7	EE8, EE9, (EE10)*	8 (9)*
Easy to use/understand	EE1, EE3, EE4	EE5, EE6, EE7	EE8, EE9, EE10	9

***Note:** interviewees partially agreed that the framework is acceptable and comprehensive

The experts from the design innovation group agreed most strongly on the framework's potential usefulness, regarding it as an appropriate overview of design innovation ability for UK innovative manufacturing companies much like an audit (interviewees EE8 and EE10), and for the different areas of design influences so that top-level managers/clients can better understand (interviewees EE5, EE6 and EE9). The manufacturing experts initially questioned the design innovation framework's fundamental purpose, asking whether every company at every level of business actually needs design, creativity and even innovation (interviewee EE1), asking about the difference between the design innovation framework and other management processes such as lean six sigma (interviewee EE2). The manufacturing experts' comments may be explained by their company's resistance to change (interviewee EE1), but the researcher noticed a significant change in tone from scepticism to acceptance during the course of the interviews. In the same senesce, interviewee EE4 recognised the framework's potential usefulness for his company, but also commented that it is not obvious at first glance. Interviewee EE1's comment about the need for design in businesses mentioned earlier is interesting because, firstly it shows the range of perceptions of design in the interviewee group, and secondly, it echoes the points made by the design innovation experts about the importance of top-level management's commitment to implementing design innovation in their company (Section 6.2.16).

The six design innovation benefits were regarded by most interviewees as adequately demonstrating the benefits to the company, with a good balance of detail and simplicity (interviewees EE4, EE6, EE8 and EE9) in a format which makes complex relationships easy to understand (interviewees EE1, EE3, EE5, EE7 and EE10). However, questions about their influences on the three main goals included interviewees EE3 and EE5's comments about design innovation benefits influencing all three main goals. After further explanation about the framework's intention to show the likely main direct influences, which can indirectly influence all the other goals, interviewee EE5 agreed with the arrangement of the six design innovation benefits. The evaluation experts broadly agreed on the frameworks' contents, but some further explanation was required to clarify the detailed meaning behind them.

When the three main goals of design innovation were further discussed, again the overwhelming majority of interviewees agreed with the main goals to improve different types of innovation, and it was also noted that ‘user’ (interviewee EE10) and ‘brand’ (interviewee EE8) - considered important by many design professionals - are not clearly represented. The research recognises the importance of users and branding for design to enhance innovativeness and that it is essential for design innovation. However, the research deconstructs the influences into other terminology e.g. the main elements of branding and users are conflated into ‘clear communication’, ‘work culture/environment improvement’, and ‘extensive collaboration’. This becomes even more apparent with twenty design innovation characteristics in the framework details. Interviewees EE8 and EE10 recognised this, and the high level of comprehensibility, as they went through the framework details. Interviewees EE2 and EE10 also noticed that the three main goals are in a process of innovation (creative idea generation in an optimised business environment leads to successful commercialisation). The researcher agrees with this point (see Sections 7.2.1.6 and 7.2.2) that a company’s ultimate goal is commercial success. Interviewees EE7, EE8 and EE10 mentioned that prioritisation of the design innovation’s main goals to improve innovativeness is not clearly shown in the framework. Again, this issue was resolved when they went through the entire framework booklet, as prioritisation is included in the implementation section. The overlapping areas of the three main goals and their influence on different types of innovations (product/service, process and organisational) was regarded as appropriate by almost all interviewees; although the researcher had anticipated possible arguments against the placement, the evaluation experts regarded it as logical and acceptable.

7.4.2 Design innovation framework details evaluation

The framework details included six design innovation benefit wheels, two on each page, which provide influences on one of three main design innovation goals. As shown in the previous section (section 7.2.1), each wheel shows all twenty design innovation characteristics and their primary and secondary influences which construct individual design innovation benefits. Again, the balance between detail and simplicity in the graphical representations was considered important in creating these framework details and most evaluation experts commended this effort (Table 7.4).

Table 7.4: Result of evaluating design innovation framework details

	Manufacturing (n=4)	Design/Innovation managers (n=3)	Design/Innovation consultants (n=3)	Total number agreed (n=10)
Acceptable	EE1, EE3, EE4	EE5, EE6, (EE7)*	EE8, EE9, (EE10)*	7 (9)*
Potentially Useful	EE1, EE2, EE3, EE4	EE5, EE6, (EE7)*	EE9, EE10	8 (9)*
Comprehensive	(EE1, EE2)*, EE3, EE4	(EE5)*, EE6, EE7	EE8, EE9, EE10	7 (10)*
Easy to use/understand	(EE1)*, EE3, EE4	(EE5)*, EE6, EE7	EE8, EE9, EE10	7 (9)*

***Note:** interviewees partially agreed that framework details are acceptable, useful, comprehensive and easy to use/understand

The design innovation framework details are a complex array of direct/indirect influences of design innovation characteristics. Complexity was inevitable with the many actions and effects design innovation has for innovative manufacturing companies. The evaluation experts noticed this and some commented on the complexities of understanding what the framework details represent (interviewees EE1, EE2, and EE5). This is attributable to its visual representation (interviewee EE1), too much information (interviewee EE10), possible repetitiveness of the characteristics (interviewee EE5), and an unclear distinction between direct and indirect influences (interviewee EE2). Despite these concerns, the framework details were generally understood and agreed by the overwhelming majority of the evaluation interviewees.

The design innovation characteristics were also evaluated. The discussions brought mixed opinions, the majority of the design innovation group arguing that they are a comprehensive representation of design innovation influences. However, the top-level managers of manufacturing companies had split opinions: although all agreed the characteristics are comprehensive, some queried whether they are exclusive to design innovation (interviewees EE1 and EE2). This is understandable as the research repeatedly states that the characteristics do not aim to show the influences exclusive to design innovation, but rather suggest the design innovation actions as a part of the initiatives to improve these areas. Some characteristics consist of more actions by design innovation e.g. technical design and graphics/websites, although in some areas, design innovation is only used as a initiator and mediator of information, e.g. top-level management support, business model, etc., However, time constraints meant that the level of influences were not considered in the research, so they are not included in the framework details.

There were questions about the influences (arrows pointing towards the benefits) of design innovation characteristics. Just under half the experts (interviewees EE3, EE4, EE5, and EE8) mentioned that some characteristics they consider relevant are not connected with a particular benefit (e.g. 'investment' characteristics on the 'clear communication' benefit). However, this was mainly because the experts did not notice and/or understand the legend provided with the details i.e. primary and secondary influences. The level of importance for the characteristics was also mentioned (interviewees EE5 and EE10) to make the framework detail more accessible. However, the research could not adequately prove the broad importance of each characteristic, and conversely argued against ranking them by importance because of the varied situations and circumstances of innovative manufacturing companies, leading to different priorities resulting in variable levels of importance. This is further addressed in the implementation process where the company has to prioritise the characteristics to develop, according to their situation, vision and business objectives.

7.4.3 The implementation process evaluation

The recommended generic implementation process was evaluated prior to the scenarios to present the argument for justification, and to explain the process of implementing the design innovation framework. It consists of the process itself and the design innovation matrix as a tool to indicate the maturity of design and innovation involvement. Almost all evaluation experts agreed on the logic behind the process and the matrix, and it potential usefulness for innovative manufacturing companies (Table 7.5).

Table 7.5: Result of evaluating the generic implementation process

	Manufacturing (n=4)	Design/Innovation managers (n=3)	Design/Innovation consultants (n=3)	Total number agreed (n=10)
Acceptable	EE1, EE2, EE3, EE4	EE5, EE6, EE7	EE9, EE10	9
Potentially Useful	EE1, EE3, EE4	EE5, EE6, EE7	EE9, EE10	8
Comprehensive	EE1, EE2, EE3, EE4	EE5, EE6, EE7	EE8, EE9, EE10	10
Easy to use/understand	EE1, EE3, EE4	EE5, EE6, EE7	EE8, EE9, EE10	10

The design innovation framework implementation was designed to maximise the potential use of the framework in a business setting. It therefore uses combinations of strategic management, innovation and design thinking theories to comprehend the familiar process which companies adopt to enable changes to improve company performance. This was well received by the evaluation experts, especially those in innovative manufacturing companies. However, interviewee EE8 offered the insight that the very nature of a generic process could hinder acceptability, especially coming from an external consultant. Contrasting options were provided by another design innovation group expert (interviewee EE9) who said that the thorough easy to understand process will help convince clients (innovative manufacturing companies) to consider using the process. Such contrasting arguments were anticipated as the research also argues for flexibility in using the framework in different business settings. However, as a recommendation, the process itself will be sufficient, as argued by the experts in innovative manufacturing companies. Interviewee EE2 argued that 'benchmarking' is not appropriate for 'innovation', explaining that innovation should not concentrate on what others are doing, but excel beyond that to create new products/services to lead the market. His point emphasising radical innovation is valid, but the purpose of benchmarking in the process is not to fast-follow the competitors; it is to better understand the company's business situation to identify and prioritise the improvement areas. All the design innovation experts agreed with the importance of having the initial stage of 'acknowledgement of problem/opportunity', arguing that without this, the implementation process would not start.

The design innovation matrix was also well received by the evaluation experts once they understood the purpose correctly and found it potentially very useful for innovative manufacturing companies. However, there was a question about how the matrix relates to the whole implementation process (interviewee EE4) and who determines the level of design and innovation (interviewees EE1 and EE6). These questions were answered while discussing the scenarios and the experts subsequently agreed on the use and relevance of the matrix.

7.4.4 The scenarios evaluation

The use of three scenarios was fully appreciated by the experts as providing clearer understanding of the design innovation framework and its use in innovative manufacturing companies (Table 7.6). It provided answers to many questions raised from going through the framework and its details.

Table 7.6: Result of evaluating scenarios

	Manufacturing (n=4)	Design/Innovation managers (n=3)	Design/Innovation consultants (n=3)	Total number agreed (n=10)
Acceptable	EE1, EE2, EE3, EE4	EE5, EE6, EE7	EE8, EE9, EE10	10
Potentially Useful	EE1, (EE2)*, EE3, EE4	EE5, EE7	EE8, EE9, EE10	8 (9)*
Comprehensive	EE1, EE2, EE3, EE4	EE5, EE6, EE7	EE8, EE9, EE10	10
Easy to use/understand	EE1, EE2, EE4	EE5, EE6, EE7	EE7, EE8, EE9	9

***Note:** interviewees partially agreed that scenarios are useful

The scenarios were comprehensive enough to provide elements which all experts in innovative manufacturing companies could relate to in their current or past situations. This does not mean the companies where experts work share exactly the same problems, but there are recognisable segments in the scenario which the experts could relate to. The scenarios also helped the design innovation consultant experts reflect on their previous work with UK innovative manufacturing companies. The recommended priority areas and programmes in the scenarios were also broadly acceptable to the consultants. Some experts became so deeply immersed in the scenarios that they started to 'consult' on how different design innovation characteristics could be used to improve the situation in the scenarios (interviewees EE4, EE9 and EE10) - a positive sign that the design innovation framework and subsequent implementation process are intuitive enough that the experts immediately started to use them when a situation (scenario) was given. However, questions arose about how companies would prioritise the areas to develop (interviewees EE3, EE4 and EE6), which raises a fundamental question about the scope of the research. This research aims to provide a comprehensive overview of design innovation to improve innovativeness (the framework) with design innovation actions identified as having benefits for innovative manufacturing companies, which lead to improving different types of innovation. However, the research cannot provide a generalised way or an exact method of identifying the areas to develop in the framework, as it is not within the scope of the research.

Interviewees EE8 and EE10 suggested showing in the design matrix the prospective stages of design maturity/innovation involvement after implementation, to show how applying the design innovation framework could change the company's position. Most of the evaluation experts clearly understood the description of each stage but questions arose about the presentation of 'identify design innovation characteristics and its elements to develop', as it can be tedious to go through (interviewees EE1, EE5, EE7 and EE10).

7.5 Finalisation of the design innovation framework

The evaluation of experts from innovative manufacturing companies and design innovation consultancies provided suggestions for improving the framework and implementation process. These recommendations are aggregated to increase the validity of the research outcome and to increase acceptability, potential usefulness and ease of use/understanding. As the overwhelming majority of experts agreed on the framework's comprehensiveness, details and implementation, including the scenarios, the contents of the framework will not be changed. Details of the improvements suggested for each stage of the framework will be discussed in the following section, however, the experts' recommendations for the framework as a whole include:

- Better/simpler explanation of terminologies (interviewees EE1, EE2 and EE10),
- Better visual overview in the introduction (the researcher's observation),
- Use of colour to more easily understand different elements throughout the framework booklet (interviewee EE4).

The research and framework terminologies and overview were explained in the introduction. However, prospective users (the experts) often skipped the introduction because of the amount of information there, leading to many misunderstandings of the framework. The framework and subsequent booklet were made in greyscale in order to reduce the file size, which reduced the opportunity to use colour to provide more vibrant and distinguishable contents. These issues are addressed in the final design innovation framework (see Appendix H).

7.5.1 The final design innovation framework

The design innovation framework improvements areas identified during the evaluation interviews were:

- Clearly indicate that each design innovation benefit can also influence other main goals of design innovation (interviewees EE3, EE4, EE6, EE9 and EE10)
- Indicate where brand and users are in the framework context (interviewees EE8 and EE10)
- Explain the meaning of 'total innovation' (interviewees EE1 and EE2)
- Show the process to successful innovation, i.e. creative idea generation in an optimised business environment to become commercially successful (interviewees EE2, EE5, EE6, EE8)

Several iterations have been made, considering the experts' suggestions to create the final design innovation framework. Figure 7.9 shows the final version of the framework, placing greater emphasis on the clarification by introducing colours and also by placing the interrelating relationship (dotted line) between six design innovation benefits inside the benefits. The explanation of the user and brand is added on the side to clarify that they are within the six design innovation benefits, and not omitted from the framework. The visual representation of the process-oriented relationship between the three main goals of design innovation has replaced the page only explaining the meanings (P.3 of the beta version), showing that creative idea generation in an optimised business environment leads to successful commercialisation (Figure 7.26).

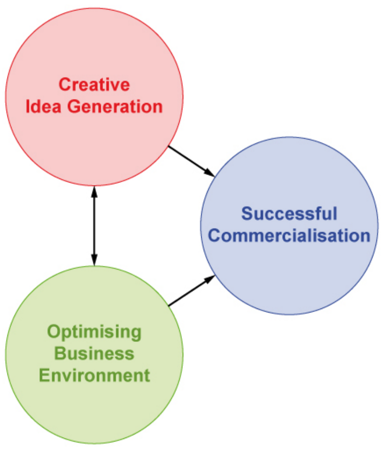

Figure 7.26: Relationship of the three main goals of design innovation

7.5.2 Finalisation of design innovation framework details

The contents of the design innovation framework details were also regarded as comprehensive and acceptable by the evaluation experts. However, certain elements were identified to enable better understanding of the framework details:

- More distinction between influential areas and non-influential characteristics (interviewees EE1, EE6, EE9),
- Less emphasis on the design innovation spectrum to emphasise the relationship of characteristics and the benefit (interviewee EE10),
- More emphasis on the meaning of the arrows (primary and secondary influences) and explanation of faint influences from other characteristics (interviewees EE3, EE4, EE5, EE6, EE9 and EE10).

The design innovation framework details were finalised with due consideration of the evaluation experts' comments, including reducing the emphasis of the design innovation spectrum and non-influential characteristics. A further explanation of the design innovation characteristics' influence on each benefit was also added to clarify common questions raised by the experts in the legend. Figure 7.27 shows an example of changes in the design innovation framework detail of 'problem/opportunity identification' and the legend.

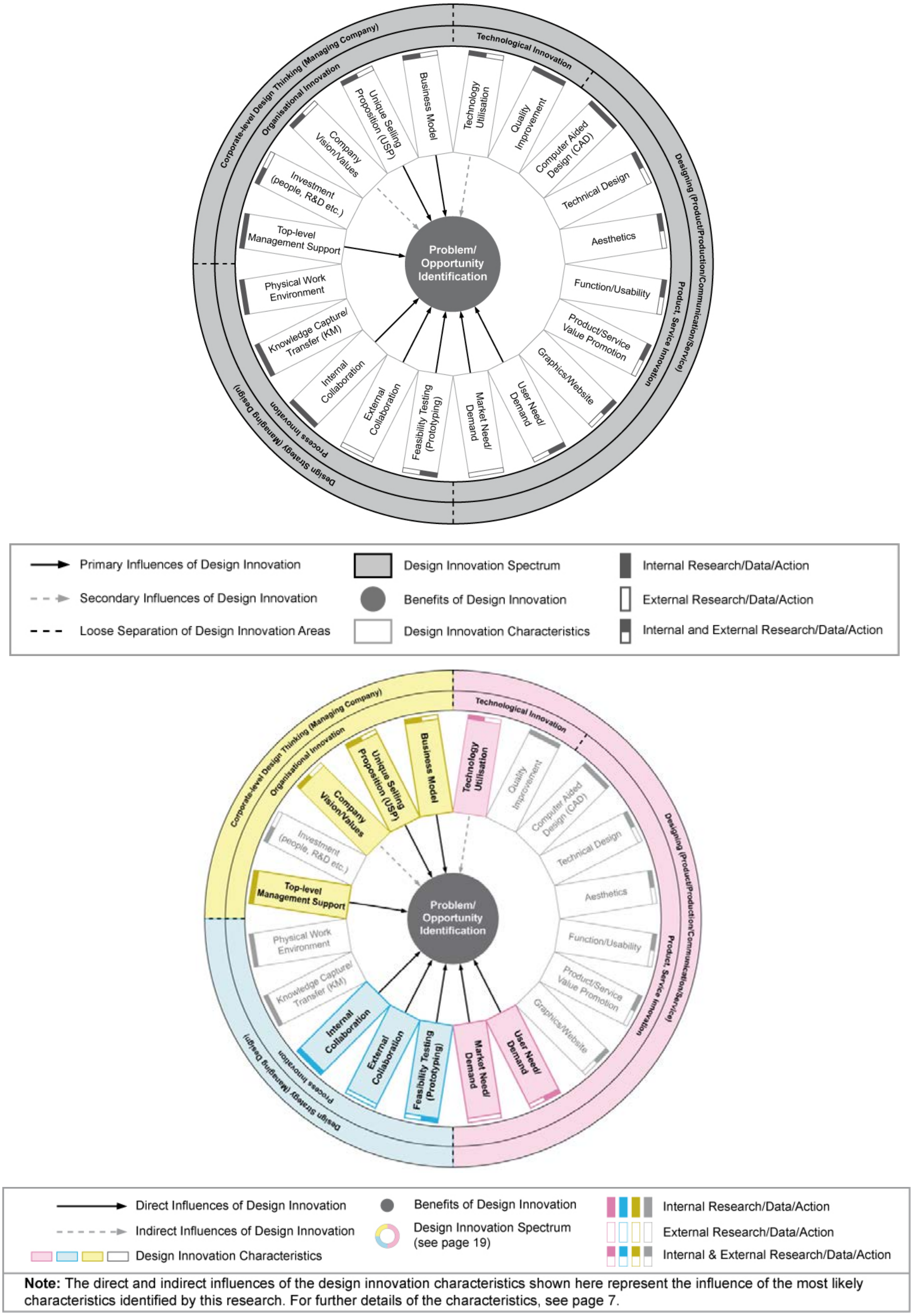

Figure 7.27: Comparison between beta (upper) and final (lower) versions of the design innovation framework detail and its legend

7.5.3 Finalisation of implementation scenarios

The evaluation experts regarded the implementation process as showing sufficient easy to understand information, but suggestions for improvements for the scenarios include:

- Indicate expected end-result for the company in the design innovation matrix (interviewees EE8 and EE10)
- Better representation of 'identify design innovation characteristics and its elements to develop' stage of the implementation process (interviewees EE1, EE5, EE7 and EE10)

These comments led to changes in representation of the scenarios, including a separate page on the 'identify design innovation characteristics and its elements to develop' stage, as the researcher agreed on the significance of this stage in explaining the use of the framework to increase innovativeness for companies represented in the scenarios. The changes are implemented and comparison between the beta and final version for scenario 1 as an example is shown in Figure 7.28 for design innovation matrix, and Figure 7.29 for the 'identify design innovation characteristics and its elements to develop' stage of the design innovation framework implementation process.

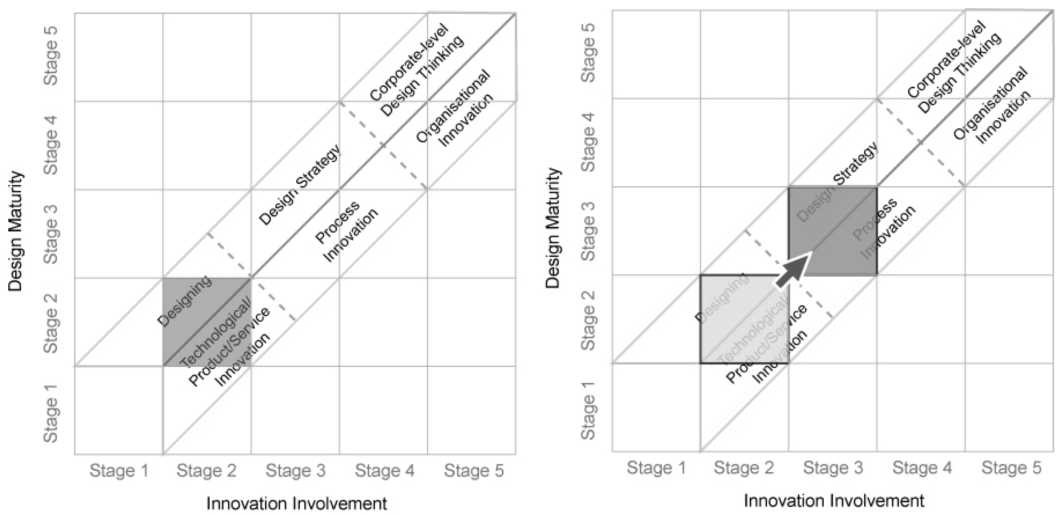

Figure 7.28: Comparison between beta (left) and final (right) versions of the design innovation framework implementation scenario (design innovation matrix for scenario 1)

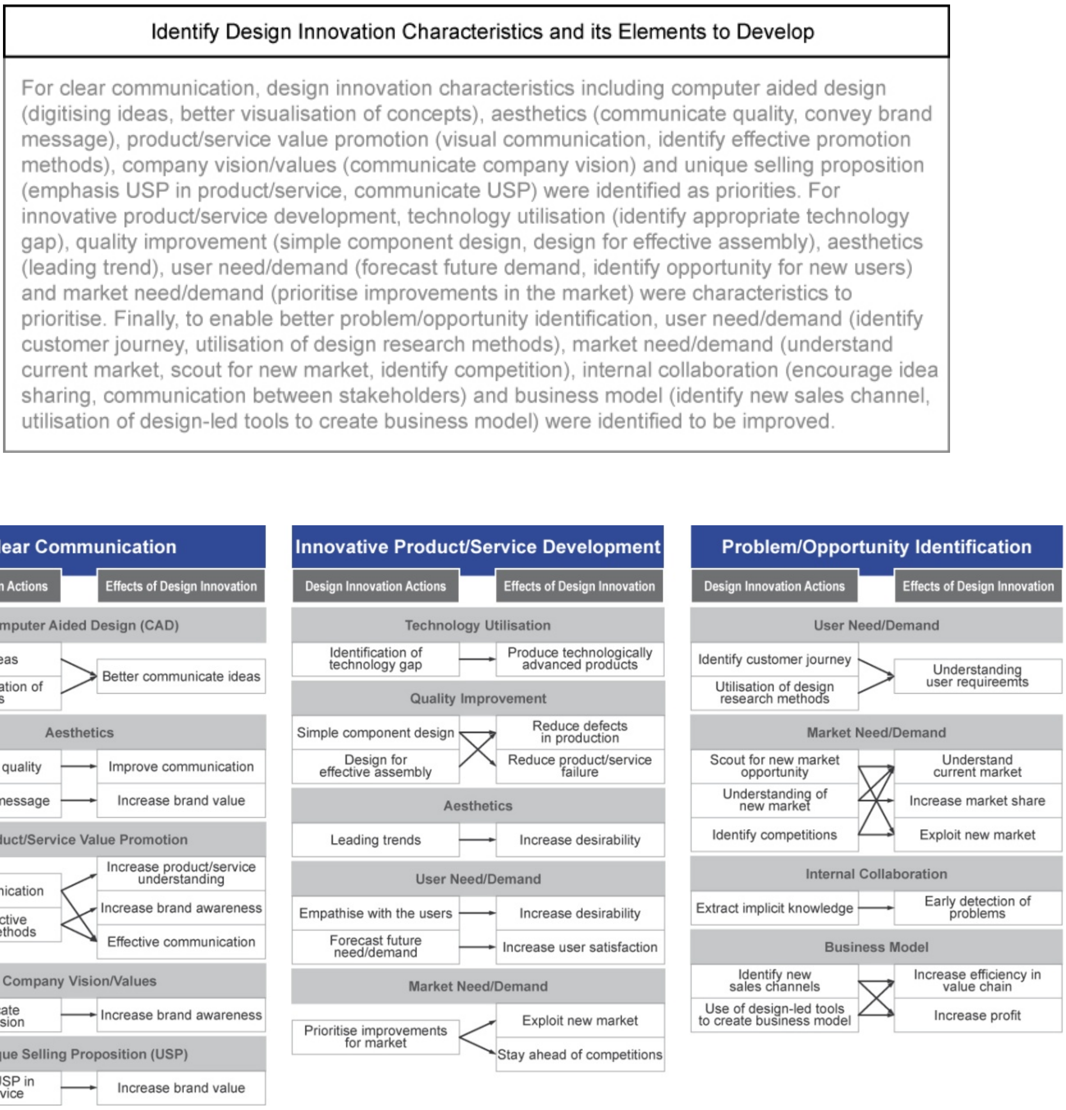

Figure 7.29: Comparison between beta (upper) and final (lower) versions of the design innovation framework implementation scenario ('identify design innovation characteristics and its elements to develop' stage of the framework implementation for Scenario 1)

7.6 Chapter summary

Synthesis and discussion of the research findings led to recommendations in the form of design innovation framework and its implementation to further improve innovativeness of UK innovative manufacturing companies. The evaluation of the initial framework and implementation was discussed to validate the research outcome with prospective users of the framework, who are also regarded as experts in manufacturing and design innovation. The evaluation raised some questions, but when further explanations were provided almost all questions were clarified. The finalisation of the framework and implementation process was therefore mainly an improved representation of the information already identified from the research, as suggested by the experts, in order to increase acceptability, potential usefulness and ease of use/understanding.

The next chapter discusses the key outcomes of the research by comparing them with the research aim, questions and objectives. The limitations of the research will also be discussed, and the thesis will conclude with recommendations for future research.

Chapter 8. Conclusions

8.1 Introduction

This thesis hopes to contribute to the knowledge of design innovation in the UK innovative manufacturing context. It reports, analyses and discusses the sequence of studies, constructing an empirical research which can be adopted in practice to enhance innovativeness in UK innovative manufacturing companies, by applying the design innovation framework and it implementation process. This final chapter concludes the research journey with an overview of the research questions, aim and objectives and the research findings. It also discusses the main contributions and limitations of the research, suggesting further researches which could overcome the limitations and enrich the knowledge created by this research. Overview of this chapter is shown in Figure 8.1.

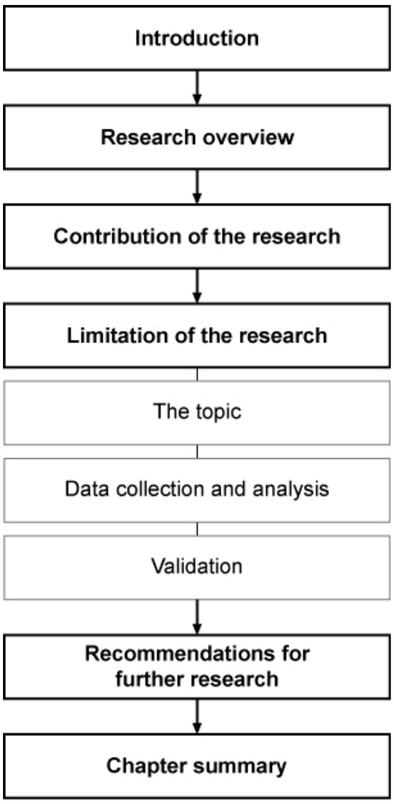

Figure 8.1: Chapter map

8.2 Research overview

The research aims to create a design innovation framework to provide a comprehensive overview of design innovation actions and influences for UK innovative manufacturing companies, to further improve innovativeness and enable sustained growth and increased competitiveness. Three main questions arose from the initial enquiry to the topic and further literature review:

(Q1) What are the perception and utilisation of design in UK innovative manufacturing companies?

(Q2) What are the design innovation characteristics that enable UK innovative manufacturing companies to further increase their innovativeness?

(Q3) How can innovative manufacturing companies implement design innovation and embrace the benefits to improve business performance?

The research was divided into three main phases to answer these questions effectively (Figure 8.2). Phase One addressed the first research question by exploring the context of design and innovation in UK innovative manufacturing through the literature review, four exploratory interviews with manufacturing academics, a questionnaire survey of forty-eight innovative manufacturing companies, and eleven in-depth interviews with manufacturing experts. Phase Two answered the second research question by developing the theory of design innovation and its implications for innovative manufacturing. The main information sources were literatures, case studies of forty-six innovative manufacturing companies and twenty-two in-depth interviews with design innovation and manufacturing experts. Phase Three evaluated the theory built from the research, using ten in-depth interviews with prospective users of the design innovation framework and its recommended implementation process. The validity and usability of the research was increased by using interviewees – who worked both externally and internally with innovative manufacturing companies – who were regarded as experts in design innovation, and top-level manager interviewees from innovative manufacturing companies. The overview of the research questions and objectives in relation to the thesis chapters are shown in Table 8.1.

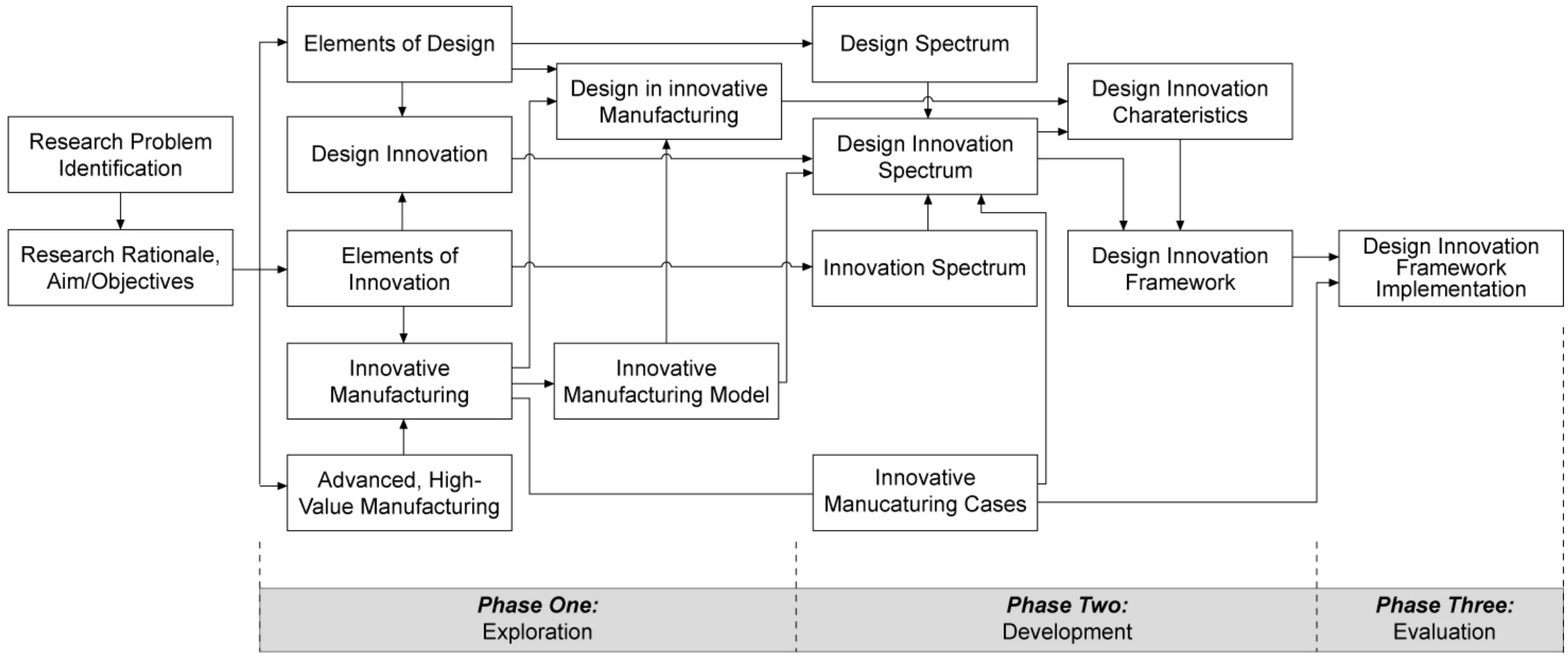

Figure 8.2: Research process overview

Table 8.1: Index of thesis chapters addressing the research questions and objectives

Research Questions	Objectives	Chapters
-	(OB1) To review existing theories about the use of design and innovation in businesses, to understand the scope of the relationship between design and innovation	Chapter 2
-	(OB2) To investigate UK manufacturing's contribution to the UK economy and national competitiveness and establish a definition of UK innovative manufacturing, and its relationship with advanced and high-value manufacturing, to identify their strategic importance	Chapter 2 Chapter 4
(Q1) What are the perception and utilisation of design in UK innovative manufacturing companies?	(OB3) To investigate UK innovative manufacturing companies' current perception and utilisation of design, in order to understand the issues surrounding design	Chapter 4
(Q2) What are the design innovation characteristics that enable UK innovative manufacturing companies to further increase their innovativeness?	(OB4) To identify the relationship between design and innovation by creating and evaluating a design innovation spectrum, which is an overview of design innovation in innovative manufacturing companies	Chapter 4 Chapter 5
	(OB5) To identify design innovation characteristics containing actions and the benefits of design innovation for UK innovative manufacturing companies	Chapter 5 Chapter 6
(Q3) How can innovative manufacturing companies implement design innovation and embrace the benefits to improve business performance?	(OB6) To create and evaluate a design innovation framework, including an implementation process for UK innovative manufacturing companies to further increase innovativeness and encourage business growth.	Chapter 7

The exploration of innovative manufacturing in the first phase of the research established its role as an enabler for different types of innovation to enhance business values. However it also addressed many companies' restricted use of design, because design is often narrowly perceived only as discipline-based design e.g. product or graphic design (Chapter 4). In order to expand the view of design in context of innovation and business, a design innovation spectrum was developed in the second phase of the research (Chapter 5). It provided an overview of where and how design can more broadly influence a business context, and how different types of innovation relate to areas of the design spectrum. The identified areas are heavily interlinked and difficult to separate, however, to illustrate the overview of the various areas, the 'design' were broken down to include designing, design strategy, corporate design thinking, and 'innovation' areas which include technological, product/service/process and organisational innovation.

The development stage in the second phase of the research continued with a detailed study of the design innovation characteristics to formulate design innovation actions, and their effects and benefits for innovative manufacturing companies (Chapter 6). Twenty main design innovation characteristics for innovative manufacturing companies were identified: technology utilisation, quality improvement, computer aided design (CAD), technical design, aesthetics, function/usability, product/service value promotion, graphics/website, user need/demand, market need/demand, feasibility testing (prototyping), knowledge capture/transfer (KM), external collaboration, internal collaboration, top-level management support, physical work environment, investment, company vision/values, the unique selling proposition (USP) and the business model. These characteristics were identified as being present in all business levels, from activity (operational), strategic, to organisation level. The characteristics were therefore positioned in the design innovation spectrum to provide placement of each characteristic in a business context.

The design innovation spectrum and characteristics were then further analysed and aggregated to construct a design innovation framework and an implementation process (Chapter 7). The design innovation framework is an overview of the relationship of the design innovation characteristics and their business benefits to enhance innovativeness in UK innovative manufacturing companies. The research identified six main benefits of design innovation: problem/opportunity identification, extensive collaboration, work culture/environment improvement, efficient process development, clear communication, and innovative product/service development. The influences of these benefits are consolidated into three main goals, identified as creative idea generation, optimising the business environment, and successful commercialisation, which together contribute towards product/service, process and organisational innovation improvements. The implementation process is subsequently designed to suggest an optimal use of the design innovation framework. As part of the implementation process development, the design innovation matrix - which combines the design maturity and the level of involvement of innovation in a company - was developed to indicate the level of a company's design innovation. A scenario technique was also used to connect the concept to a real-life situation derived from the case studies including: (i) 'Company A', with a decreasing market share and customers, (ii) established ‘Company B’, which hopes to expand its business, and (iii) technology entrepreneurial start-up ‘Company C’.

Phase Three evaluated and finalised the framework and implementation process in order to increase the validity of the theory and enhance the framework’s usability. The overwhelming majority of the evaluation experts agreed with the theory created through the research, offering important suggestions to improve its usability, including clearer visual representations using colours with a better balance of simplicity and detail, to enhance its acceptability, potential usefulness and ease of use/understanding.

8.3 The research contribution

This research was undertaken to understand the dynamic relationships of design and innovation in UK innovative manufacturing companies, considering theoretical knowledge creation principally for the academic disciplines of design management. It will also be of interest for the innovation management disciplines to understand the extensive effects of design in managing innovation in a manufacturing context, how different types of innovation relate to the actions undertaken to maximise innovativeness using the medium of design. The research also contributes towards the practical application of the theory, by providing a comprehensive overview of the action, effects and benefits of design innovation in an accessible visual framework and recommendations for an implementation process, which innovative manufacturing companies and design supporting organisations can use to understand and apply design innovation in their practice to systematically increase innovativeness to provide increased competitiveness and sustain growth.

Theoretical contributions

The influence of design on innovation is well documented where innovation is often regarded as a natural outcome of the design process. Design is needed to enable innovation, especially in manufacturing companies, but the design used in this context is often limited to technical design e.g. design for manufacture and discipline-based design (i.e. product and graphic design etc.). It is therefore predominantly interpreted as an activity which is part of a new product development. Design management theories address the importance of using design as a strategic tool, but there is still little empirical research about how different areas of design - designing, design strategy and corporate-level design thinking - apply to similarly extensive areas of innovation, including technical, product/service, process and organisational innovation, especially in the innovative manufacturing context. Fragmented theories of design and innovation add to the confusion about the specific benefits of design innovation in innovative manufacturing companies. Therefore this research adds knowledge to the theory to comprehend the complexity of expanding design and innovation in the innovative manufacturing context through developing design innovation spectrum and framework. The research outcome provides a comprehensive overview of the effects of different areas of design in innovation through the accumulation of theories, and design innovation and manufacturing experts' opinions. This contribution to knowledge will be especially relevant in bringing together theories of design management and manufacturing management to develop a more comprehensive theory of innovation management for innovative manufacturing. Moreover, for design management academics with extensive knowledge of design influences in manufacturing companies, the visual framework of this research is bridge to better understanding the effects of design on different aspects of innovation. Similarly for innovation management academics, the research will contribute to better understanding the complexity of expanding areas of design influences to enable innovation in a commercial context.

Practical contributions

The research recommends the design innovation framework and its implementation process to be used to address UK manufacturing companies' poor uptake of the extensive areas of design (designing, design strategy and corporate-level design thinking) and to provide such companies with a comprehensive overview of the benefits of design innovation. The research contributes towards building better understanding and identifying practical design innovation actions to improve innovativeness which can be used by both innovative manufacturing companies and design innovation consultancies. The framework is specifically designed to be easily understood, using a simple visual diagram to demonstrate the relationship between design innovation and the essential elements which can enhance innovativeness; it is also sufficiently comprehensive to identify company- or sector-specific areas of design innovation improvements. The identified areas can be used either when a manufacturing company seeks support from design innovation consultancies or when writing a design innovation brief. The recommended implementation process aims to contribute towards systematically making a company more innovative, by improving technological, product/service, process and organisational innovation, and prioritising and developing different design innovation characteristics, as appropriate for the company. This will be potentially useful for top-level managers and design/innovation managers of innovative manufacturing companies when creating an innovation strategy for the company. The research recommendations also include three scenarios with examples of situations which managers of innovative manufacturing companies could easily relate to, potentially enhancing adaptability, to increase the practical contribution of the research. The framework also provides a blueprint of design innovation actions which could be used by managers to prioritise the company's design innovation activities, to develop a specific innovation area which will increase the company's competitiveness. These potential contributions were agreed during the evaluation phase by top-level managers and design/innovation managers of UK innovative manufacturing companies (Phase Three, Chapter 7), who recognised the potential benefits of the framework and its implementation.

The research contributions extend to commercial (consultancies) and non-commercial (governmental and non-governmental) organisations which support the use of design innovation in innovative manufacturing companies. The design innovation framework developed through this research provides a systematic map of design innovation influences to enhance innovativeness. It can therefore be used as a tool to potentially guide innovative manufacturing companies to identify and prioritise specific areas of innovation to develop, managed to suit individual companies' specific requirements.

8.4 Limitations of the research

The research has limitations in the following areas: (i) the topic, (ii) measurements and analysis, and (iii) validation. The limitations are made explicit throughout the thesis which addresses the complexities of the topics of design and innovation in the business environment, using a range of theories and discussions about the meaning, values, parameters, roles and effects of design and innovation. The inherent limitations of measurement and analysis apparent in data-gathering and analysis methods could be further investigated. Throughout the research, measures were taken to increase the validity of the outcome, but it still has certain limitations.

8.4.1 The topic

Design and innovation are complex topics with countless interpretations and applications in businesses, depending on the situation, perspectives, and the internal and external culture of the company. Synthesising two broad topics into one is inherently difficult and has limitations relating to the potential over-generalisation of the different types of design and innovation. As the focus of the research was to provide a comprehensive overview of design innovation, further limitations arose where the research was unable to investigate more deeply into each types of design and innovation identified in this research. Where possible the research addresses the similarities and differences of the two topics, to provide a means to critically analyse the relationship, but the interlinking relationships between the different types of design and innovation were not addressed in-depth. Furthermore, the research did not systematically focus on the effect of innovation on business performance – a topic still actively being debated which combines the study of the boundary of innovation influences on businesses. The research recognises this issue, broadly identifying through extensive quantitative and qualitative research that innovation is indeed recognised as a means to improve company performance and is therefore an important agenda for companies around the world.

The research is limited to innovative manufacturing companies in the UK, chosen because of the sharp rise in attention to the industry, particularly after the 2008 financial crisis. The utilisation of the wider design spectrum has low priority in manufacturing where companies regard design as an important asset, but limit its use to product/technical design. This research focuses only on innovative manufacturing companies because of their apparent acceptance of the value of innovation. The category of identifying the innovative manufacturing companies is deliberately broad, i.e. not limited to product launches and financial achievements, as the research recognises different types of innovation and seeks to identify innovative manufacturing companies through their efforts to become more innovative. The research argues that the varying levels of companies' innovation may make a company 'less innovative', rather than 'not innovative'. However, a further research limitation is that defining innovative manufacturing companies can be open to debate. The UK was chosen for investigation to eliminate issues of national character and culture, and governmental support and regulations. Sampling of data collection was therefore only in UK cases which adds another limitation of the research.

8.4.2 Data collection and analysis

The research data collection methods also had limitations. As the research predominantly used qualitative research methods - exploratory interview, case study and in-depth interviews - there was no universally accepted formula for acceptable sample numbers to identify appropriate sample numbers for generalisation. As explained in Chapter 3, the research follows a generous range of appropriate samples numbers stated in the literatures (two to twenty-five), with the appearance of theoretical saturation during the interviews: four interviews with manufacturing academic experts in the exploratory interview, forty-six cases for the case study, twenty-two in-depth interviews with design innovation and manufacturing experts, and a further ten interviews with prospective users of the framework. Theoretical saturation in terms of general ideas and most of the identified design innovation characteristics, however, sometimes produced differing or opposing opinions on the same topic, or entirely new topics talked about by new interviewees. This limitation is inevitable with qualitative research which is inherently behaviourally biased. Time constraints prevented addressing this further by conducting more interviews and using techniques such as multi-coding. Furthermore, the categories of coded data (i.e. design innovation characteristics) were given equal status where they were all considered important without systematically 'ranking' the categories. Although it could not be justified in depth during the research, this was because the researcher identified that the importance of characteristics differs depending on the situation, strategic direction, sector, culture and top-level management influence in innovative manufacturing companies.

The exploratory questionnaire survey also had limitations. Data sampling was conducted using non-probability sampling because of the undefined population size. This limited the data to be validated statistically to enable generalisation, but the triangulation method was used to compensate the limitation, although using probability sampling would have enriched the data and subsequent analysis of the questionnaire survey.

8.4.3 Validation

The validity of the outcome was considered from the beginning of the research and continuous efforts were made to increase the validity by using data and method triangulation methods, and qualitative evaluations for the design innovation spectrum, the framework and the implementation process. However, some limitations remain on the validity of the outcome of the research because it could not be implemented in a real-life situation. A booklet explaining the framework and its implementation, including scenarios, was used to stimulate situational interpretation of the framework in the evaluation for experts' business practices, relying on likely possibilities rather than records of real-life situations. There were opportunities to apply the theory generated by the research in the evaluation experts' own companies, but time constraints meant they could not be implemented.

8.5 Recommendations for further research

The methodology and findings of this research provide the foundation for further research to create more robust evidence of the effects of design innovation in innovative manufacturing companies, by addressing the limitations already mentioned. During the research process further research areas were identified also, which will build on the knowledge created by this research. Therefore, further research could include:

1. This research provided a comprehensive overview of the relationship between types of design (designing, design strategy and corporate-level design thinking) and innovation (product/service, process, organisational innovation) in the manufacturing context. However, more detailed research on the interlinking influences between different types of design or innovation would enhance the understanding of the effects of design innovation on manufacturing companies.
2. The research identified that the design innovation characteristics are interrelated, but it was not possible to quantify the degree of interdependency. Further research could address this issue by investigating the statistical relationship between the characteristics and the perceived 'ranking' of importance for innovative manufacturing companies and/or design professionals.
3. An innovative manufacturing company comprises several different departments. Further research is recommended to investigate how design innovation affects the dynamics of business culture, comparing before and after using the design innovation framework.
4. The research could be replicated in different groups of cases, including different industries (e.g. service, financial, tourism etc), different countries (e.g. developing countries or other developed countries in different manufacturing environments), and different firm sizes (i.e. large, small-medium and micro enterprises), to investigate whether a similar framework and implementation process emerges.
5. Action research could be undertaken of implementation of the framework in innovative manufacturing companies by the companies themselves and by design innovation supporting organisations to identify further issues and possible solutions to enhance the validity of this research.

8.6 Closing remarks

The purpose of this research is to understand and describe the effect of design innovation by constructing a framework and implementation process for UK innovative manufacturing companies. It identified twenty characteristics which directly and indirectly influence the six main benefits and subsequent three goals the companies should aim to achieve. In the process, different types of innovation - product/service, process and organisational innovation - will be improved by using designing, design strategy and corporate-level design thinking. The framework was constructed and evaluated by the design innovation and manufacturing experts who had an accumulated 711 years of shared experience working for and with innovative UK manufacturing companies. The topic of design and innovation is complex, but the researcher anticipates that the outcome of this research could provide new knowledge about the complex relationship between design and innovation in the manufacturing context, greater clarity about the benefits of design innovation for innovative manufacturing companies to increase competitiveness and sustain growth, and a comprehensive blueprint for design innovation professionals and organisations to systematically help companies increase their innovativeness.

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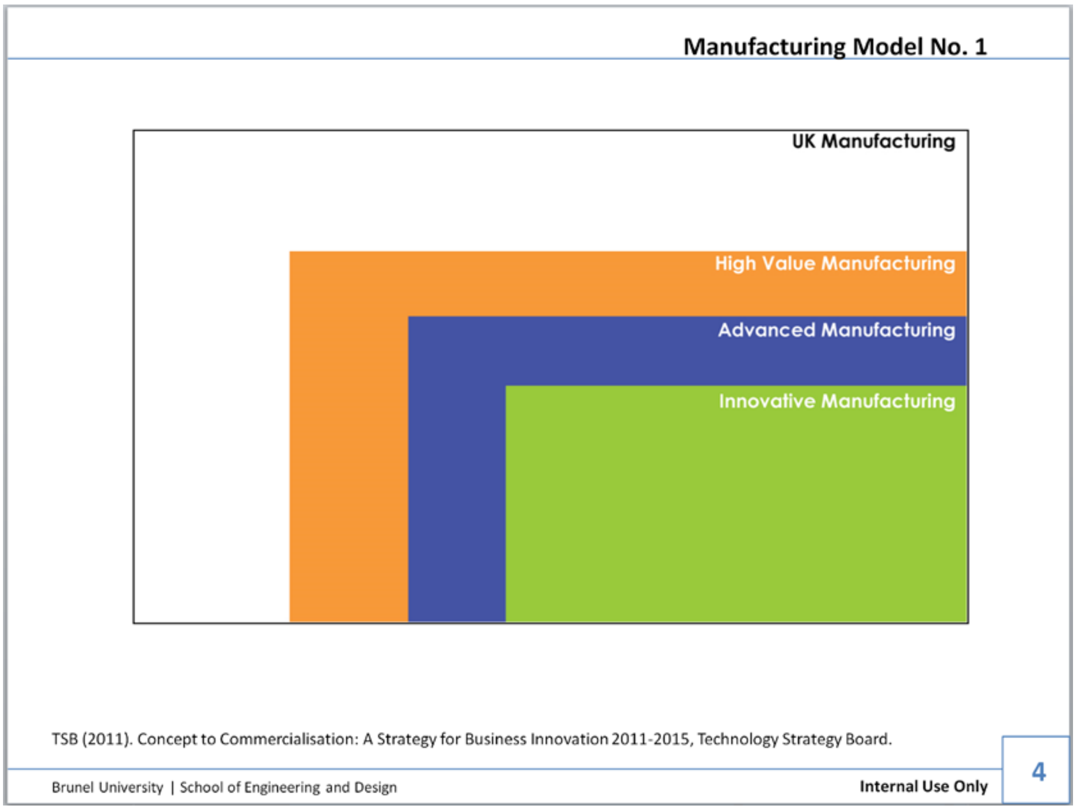
APPENDIX A: Questions for Exploratory Interviews

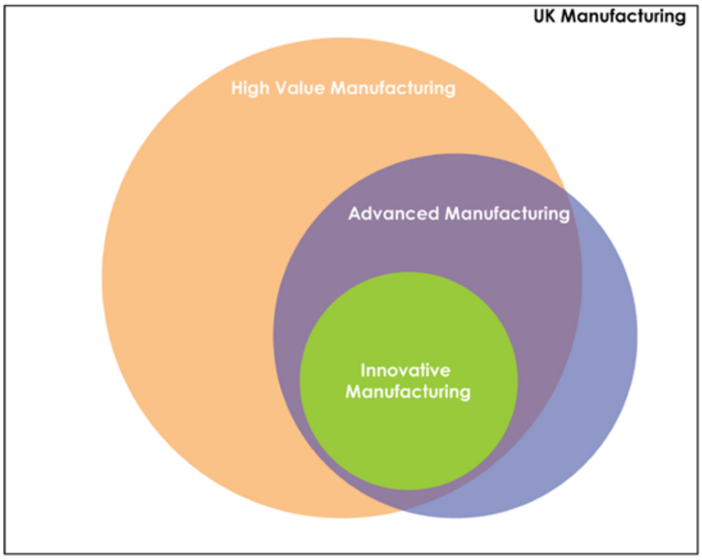
Ice-breaking Question.

How do you view the current level of competence/ competitiveness of manufacturing and manufacturing companies in the UK?

1. What would be your definition of advanced/high-value/innovative manufacturing?
2. How would you describe the innovative manufacturing sector and what are the values of that sector for manufacturing and the UK economy?
3. A literature review indicated that several manufacturing models have been created. Please comment on these models.



Manufacturing Model No. 2



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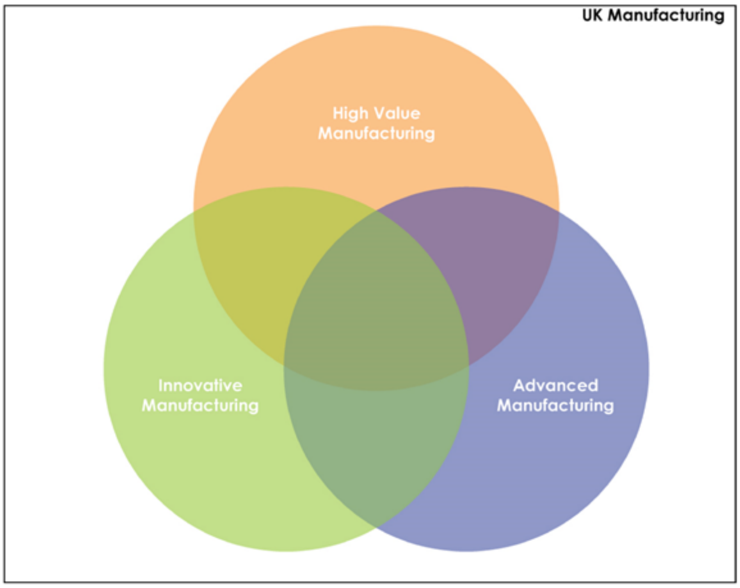
Manufacturing Model No. 3



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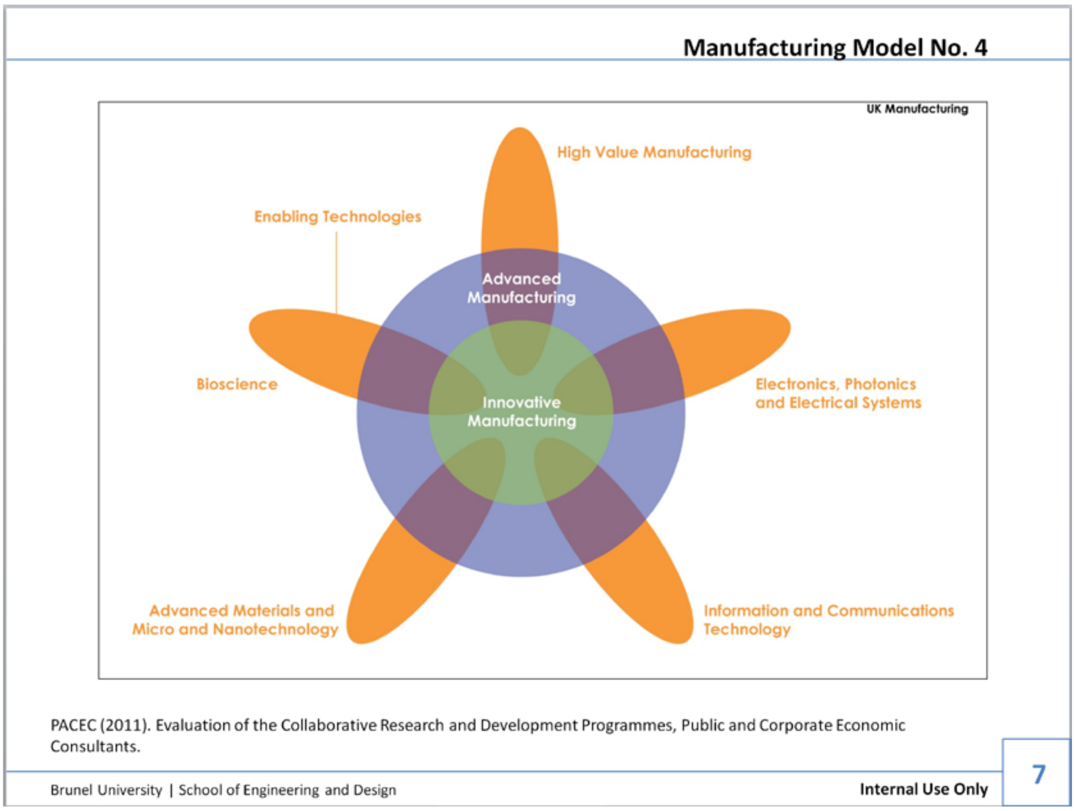


4. What are the key benefits of your research in the innovative manufacturing sector and the UK manufacturing industry as a whole?

5. What do you think is the role of design in innovative manufacturing?

5a **(N.B. If the design is only recognised as part of NPD or product improvement, discuss this question).** Do you recognise design as a strategic tool which can influence wider areas of business for manufacturing industry such as enhancing process and organisational management?

APPENDIX B: Questions for Questionnaire Survey

A survey on UK innovative manufacturing firms and the influence of design

This research is a collaborative project between Brunel University and Lancaster University to understand the role of manufacturing and in particular, innovative manufacturing in the UK and the role of design within the industry. This survey aims to obtain general views of UK manufacturing firms on innovative manufacturing and design which will be used to help understand the relationship between design and the manufacturing.

This survey will be strictly confidential and your personal detail WILL NOT be used in any of the reports or discussions. The result will be used for academic purpose only. If you have any questions regarding this survey, please do not hesitate to contact me.

Thank you in advance for your co-operation

Jea Hoo Na
Dr. Youngok Choi
School of Engineering and Design

Taxonomy of terms

Innovative manufacturing: Manufacturing in which the innovation in products and processes is priority and continuously invest in research and collaborative work to produce new and/or improved products and processes

Advanced manufacturing: Manufacturing that uses high level of design and/or scientific skills to produce technologically complex products and processes

High value manufacturing: Manufacturing that produces products that are of high-value in terms of price and/or industrial influence in the market

☐ We would like to enhance the understanding further by conducting an informal semi-structured interview. It would be an excellent opportunity for us to obtain valuable insight from you face to face. However, if are uncomfortable for us to contact you in this matter please tick the box.

General information about you

Job title:
Role/function:

Your name (optional):
Company name (optional):
e-mail address (optional):

1. The Company

1.1 What sector is your company in? (Please provide SIC code)

SIC Code: [ ]

If the SIC code is unknown, please write the sector below

[ ]

1.2 Approximately how many people are working in your company?

- ☐ Micro (1-9 people)
- ☐ Small (10-49 people)
- ☐ Medium (50-249 people)
- ☐ Large (250+ people)

1.3 How long has the company been in business?

- ☐ Less than 5 years
- ☐ 6-10 years
- ☐ 11-15 years
- ☐ 16-20 years
- ☐ More than 21 years

1.4 What do you consider to be the key strength(s) of your company? (Choose more than one, if applicable)

- ☐ Price
- ☐ Product aesthetics
- ☐ Technologically advanced product
- ☐ Advanced production method
- ☐ Services
- ☐ Knowledge base (inc. R&D, IP)
- ☐ Other(s), please specify: [ ]

1.5 Where is the major market for your company? (Choose more than one, if applicable)

- ☐ UK
- ☐ Europe
- ☐ Russia
- ☐ North America
- ☐ South America
- ☐ Asia (inc. India, Pakistan etc)
- ☐ Far East Asia (inc. China, South Korea, Japan etc)
- ☐ Oceania (inc. Australia, New Zealand etc)
- ☐ Other(s), please specify: [ ]

1.6 What is your main business type?

- ☐ Business to Business (B2B)
- ☐ Business to Consumer (B2C)
- ☐ Both

2. Innovative Manufacturing

2.1 How significant do you think innovative manufacturing is in giving a competitive advantage for your company?

- ☐ Very important
- ☐ Important
- ☐ Neutral
- ☐ Not important

2.2 Where do you think innovative manufacturing can be most effective?

- ☐ To create new opportunities in the market
- ☐ To develop new technologies
- ☐ To increase sales
- ☐ To drive the cost of production down
- ☐ To improve or develop new manufacturing processes
- ☐ Other(s), please specify: [ ]

2.3 What would be the most important contributor for successful innovative manufacturing in the UK?

- ☐ Research
- ☐ Design
- ☐ Technology
- ☐ Other(s), please specify: [ ]

3. Design

3.1 How would you describe design?

- ☐ Design is the tangible outcome (i.e. the output of design such as products)
- ☐ Design is a creative activity
- ☐ Design is the process by which information is transformed into a tangible outcome
- ☐ Design is the data which drives the manufacturing process(es)
- ☐ Design is a strategic tool for the business
- ☐ Other(s), please specify: [ ]

3.2 How important is design in your company?

- ☐ Very important
- ☐ Important
- ☐ Neutral
- ☐ Not important
- ☐ Highly unimportant

3.3 When is design employed in your organisation? (Choose more than one, if applicable)

- ☐ When the current product sales decline
- ☐ When competitor's sales increase with new products
- ☐ When the market share falls
- ☐ When new technology is being developed
- ☐ When a new product is in development
- ☐ All the time
- ☐ Other(s), please specify: [ ]

3.4 How would you describe spending on design for your company?

- ☐ Extra cost
- ☐ Future investment
- ☐ Necessity
- ☐ Other(s), please specify: [ ]

3.5 What is the most important end result of design for your company?

- ☐ Increase in sales
- ☐ Increase in profit margin
- ☐ Improving brand value
- ☐ Corporate image enhancement
- ☐ Cost reduction
- ☐ Streamlining the manufacturing process
- ☐ Linking to manufacturing equipment operation
- ☐ Other(s), please specify: [ ]

3.6 Where is design used in your company? (Choose more than one, if applicable)

- ☐ Research
- ☐ Development of products
- ☐ Production/Manufacturing
- ☐ Logistics and distribution
- ☐ Sales and marketing
- ☐ After sales services
- ☐ Other: [ ]

3.7 Does your company have internal design department or employee designers?

- ☐ Yes
- ☐ No

If YES, what are their roles? (Choose more than one, if applicable)

- ☐ Engineering design (inc. engineering analysis)
- ☐ Product design
- ☐ Graphic design
- ☐ Packaging design

Other: [ ]

3.8 Does your company work with external design consultancies?

- ☐ Yes
- ☐ No

If YES, what are the main roles? (Choose more than one, if applicable)

- ☐ Market/User Research
- ☐ New market exploitation
- ☐ Business strategy development
- ☐ New product development
- ☐ Production improvement
- ☐ Company branding
- ☐ Marketing
- ☐ After sales service
- ☐ All aspects of business
- ☐ Other: [ ]

Thank you very much for your time in completing this questionnaire.

If you would like to comment or suggest anything that is not covered by this questionnaire, please feel free to write your suggestion below.

APPENDIX C: Case Study of UK Innovative Manufacturing Companies

Name (Scenario contribution)	Problem	Input (Company commitment)	Process	Product / Service Innovation	Process Innovation	Organisational Innovation	Business Benefit	Comments
Design Council Case Studies								
Gipple (A, B)	Further growth and effective design within NPD.	Top management commitment. Dedicated special project manager £40k investment to upgrade Ideas and Innovation Centre	Workshop (with DA) to identify key issues and projects to add value. Streamlining opportunity finding process. Visit Innocent Drinks to benchmark stimulating work place	n/a	Streamlined NPD process. Identification of viable idea early in the development phase. Strengthened focus in NPD	Dragon's Den-inspired idea competition (internal). 'Grinnovate Framework' to bring people (employees) together. Creation of an Innovation team (10 people)	Increase growth (10%/yr). 25% turnover every year from products less than 4yrs old	The company is employee owned company (GLIDE-Growth Led Innovation Driven Employee Company Ltd) - encourages ownership, dedication,
Key references: http://www.designcouncil.org.uk/knowledge-resources/case-study/gripple, http://www.gripple.co.uk/								
James Heal (A)	Business growth - internationally. DA identified: inconsistency in communicating its product and brand, and threat of copycats and price competition from the far east	Top management commitment Connection between company and appropriate experts (design)	Analysis of the business with the management (meetings & workshops). Identification of problems in operations. Design brief creation for rebranding Connecting with design experts (external)	Strong brand and consistent, high quality offering (user-centred design) Harder to copy products	n/a	Provided solutions to wide range of business issues including setting company vision and strategy.	Sales increase 64% in 4 yrs Sales increase 13% YoY with international business increase. Increased demand	The company is acquired by Boston based Battery Ventures
Key References: http://www.designcouncil.org.uk/knowledge-resources/case-study/james-heal, https://www.james-heal.co.uk/, http://www.yorkshirepost.co.uk/business/business-news/james-heal-bought-by-venture-capital-firm-after-68-years-in-repper-family-1-6865813								

Naylor Industries -Yorkshire Flowerpots (A)	Face extinction due to construction industry recession and erosion of the clay pipe (Nayor industries' main product) Needed new income stream - new market	CEO's commitment to develop marketing and business strategy with design professional (DA)	Workshop and series of meetings. Identify weakness in company's current approach- need for systematic product development, and need for clearer branding. Connecting with design expert	Branding- emphasis on 'Britishiness' and quality of product New business name, logo, merchandise and marketing material	Blueprint for new product development	Identified new market opportunity by using existing capabilities	Sales up by £2m in 2012 over £3m in 2015. Expanded global sales (10% of group turnover)	New business model development through extensive support from the Design Associate- design helping to see possibilities 'outside the box'
Key References: http://www.designcouncil.org.uk/knowledge-resources/case-study/naylor-industries, http://www.yorkshireflowerpots.co.uk/, http://www.naylor.co.uk/								
Owlstone Nanotech (C)	Ground breaking technology but difficult to explain the technology, attract investors, identify right routes to market	Founder commitment to integrate design process to improve business vision and strategy	Working with the design experts to identify communication methods to better explain complex technology to investors.	Corporate identity- increase credibility (Mostra)-brand identity, marketing materials, websites product launch within two yrs	Create brief for a creative agency- holistic design management simple prototype building process to help test new applications	Develop USP and strategy. Develop the pitch to potential investors Identify intermediate products to build visibility and gain confidence among investors	$15m investment	Start-up company with technology but no route to the market helped by design as a principle of creating value and vision for the company.
Key References: http://www.designcouncil.org.uk/knowledge-resources/case-study/owlstone, http://www.owlstonenanotech.com/, http://www.bloomberg.com/research/stocks/private/snapshot.asp?privcapId=24211126								

Navetas (C)	Lack of knowledge to develop mass-market product. Seed Investment needed	Founder commitment to invest resources in design-led development	Identification of key issues-manufacturing, installation, data presentation to users	Visual communications showing the product in different user scenarios for potential investors Shared vision communication (visualisation)	n/a	Company strategy development through identifying the market and understanding the needs of potential consumers and investors.	Secured £900k seed funding	Albeit the development through design, the company is now very different from the case study described from the Design Council.
Key References: http://www.designcouncil.org.uk/knowledge-resources/case-study/navetas, http://www.navetas.com/, http://www.cambridge-design.co.uk/case-studies/navetas-smart-energy-monitor, https://www.greentechmedia.com/articles/read/the-smart-meter-that-can-tell-your-tv-from-your-ac								
Sugru (C)	Launching a new company-how best to articulate the company's vision with clarity and impact	Founder-CEO commitment. Connection between company and appropriate experts (design)	Creative & analytic sessions. Identification of what made the technology unique.	Brand communication within limited marketing budget. Website and packaging	Unique communication (external) process development	Clarify and articulate what the company does and stands for (vision). Refine business model. Help build clear and ambitious business strategy	£1 m turnover in 18 months. Additional £350k funding	Online community under company's slogan 'hack things better' is effective way to increase the customer base and tell brand story
Key References: http://www.designcouncil.org.uk/knowledge-resources/case-study/sugru, https://sugru.com/about, http://www.viadynamics.com/ventures/sugru/								
DME Award Winners								
Nightingale Care Beds Ltd. (A)	No sales due to lack of functionality, out dated with regulations, high competition and	Financial support (emergency finance from the directors and investors). Blue sky brief	NPD with limited budget, time and high regulatory specifications. Driven by MD (Nigel Quinn)	New 'Dropping hinge' to allow dynamic pressure redistribution. ProAxis electric profiling	Product material cost down 25%. Assembly time reduced from 8hr to 3hr. Repair and maintenance cost	Royalty arrangement with new control system developer when they had no money to pay	Sales increased 287%. From loss of £200k to profit of £185k in 4 yrs.	Classic case of how product development with thoughtful design and engineering

	dated looks	to design consultancy (PDR). Enforce designers to make decisions		hospital beds (development of two products for the price of one-product variation)	down 30%	them. Business model: Rental service- emergency 4hr, 24:7, 365 days a year		can benefit a flailing company
Key References: http://www.designmanagementexcellence.com/portfolio/nightingale-carebeds-hm-first-time-design-project/, http://www.nightingalebeds.co.uk/product-range/bariatric-beds/proaxis-plus/								
Thrislington cubicles (A)	Competitive, oversaturated market	Enough time and money in design process- 'in terms of overall cost, design is cheap'	Aesthetic improvement of pivoted doors. Design guideline updated periodically- cohesive approach-brand extensive research with specifiers Testing of the product	Unique pivoting doors using load bearing gas filled closers. Branding- simpler, cleaner communication. Credible website. Easy to install products	Find best element of design within business and benchmark in other design disciplines. Continued collaboration with external design agency	Expanding market overseas. Focus on education and leisure (creation of family group- Thrislinton education, and Thrislington Leisure)	Product specified by leading architects and are installed at Museum of Liverpool, MoMA, Apple flagship store Manhattan etc.	Aesthetic design combined with branding uplifted the company above the rest to achieve international presence
Key References: http://www.designmanagementexcellence.com/portfolio/thrislington-cubicles-winner-medium-size-company/, http://www.thrislingtoncubicles.com/								
Performance Health Products (B)	Slowing growth in the market.	Allowing the design team to attend international events- market research. Aiming for robust margin to be used partly as investment in new	Productive empathy. Market problem Identification. Conceptualise a solution. Search for easier manufacturing methods. Share ideas with	Increased brand clarity. User-centred range of new products	n/a	n/a	Increase in Export market from 2 to 23 (2000-2008). Increased turnover	The value of design is upheld in the document (DME poster), however, whether it applies still today is questionable.

		product/service development	other creative contributors					
Key References: http://www.designmanagementexcellence.com/portfolio/performance-health-products-hm-small-company/, http://www.v-trak.com/								
Bolin Webb (A,C)	Market needs for well-designed contemporary razor identified	MD dedication to design and market problem/need identification (e.g. using Gillett blades)	Market needs identification. Collaboration with suppliers in design process. Graphic design to build premium brand platform. Continuing design process to extend product range	Award winning product design, brand and packaging. Website development. Product with automotive finish and tactile grip	Applying design process holistically from product concept development through to retail shelf providing consist branding	n/a	Recognition by number of awards- CoolBrands, if Awards, Good Design Awards etc.	Design-led company in pure form. The product differentiated itself with 'well-designed' output
Key References: http://www.designmanagementexcellence.com/portfolio/bolin-webb/, http://www.bolinwebb.com/, http://www.bolinwebb.com/brand-story/, https://www.youtube.com/watch?v=DXzaGWHwRXc								
Specialist Precast Products (B)	Market opportunity identified through designer collaboration	CEO dedication New division- design hub. Collaboration with external design student. New budget for branding, website, and communications materials for Edward Martyn Concrete Design EMCD	From- specification received, manufacture, delivery to- project expectations discussed, designs developed & prototyped, manufacturer & quality control- deliver & review	New range of concrete products Bespoke products from 'archinecro'	Dedicated workshop space within factory for EMCD)	New business model based on designer collaboration (new market position) New dedicated division that uses same technology and expertise but target high-valued customers	Attracting and increased high-value product customer 25% turnover in year one (increased by EMCD) expects the turnover to exceed SPP project	SPP has strong intension to filer down the creative culture of Edward Martyn Concrete Designs to the rest of SPP.
Key References: http://www.designmanagementexcellence.com/portfolio/dme-award-winner-specialist-precast-products/, http://www.specialistprecastproducts.co.uk/								

dba Design Effectiveness Awards								
KANO Computer Kit (C)	Start-up company that needs to develop and launch new product in unknown market with low budget	Collaboration a design innovation consultancy to plan, develop and launch a new product and subsequent services and experience	Clear vision and specification for product from founders. Design-led development with holistic consideration of product, package and interactions with the user	Computer coding kit for all ages (powered by Raspberry Pi) Moving away from traditional product-package separation.	Launch the product funded by crowed funding platform (Kickstarter). Experience design principle applied in component and package design	n/a	Funding of £1.5 million from the Kickstarter. Multiple design awards (dba, Red Dot, Cannes Lions, German Design Award etc)	Start-up company founded with writer and designer (Alex Klein), venture capitalist (Saul Klein) and Israeli entrepreneur Yonatan Raz-Fridman)
Key References: http://www.effectivedesign.org.uk/winners/2015/industrial-design/kano-computer-kit, http://www.effectivedesign.org.uk/sites/default/files/6.1.3%20Kano.pdf, http://uk.kano.me/, http://mapprojectoffice.com/work/kano/, https://en.wikipedia.org/wiki/Kano_%28computer%29								
Touchline Flags (A,C)	High risk business strategy to change the nature of the company through creating a new product. Unreliable products in current market (competitors)	Companywide trust and commitment in external design innovation experts as partner. Professional referee experience from the founder	Collaboration with external industrial design (LA design) and electronic design (Briton EMS) agencies	Elegant, highly featured and cost effective lineman flag and signal receiver for referees (wireless alert)	New design, development and manufacturing process integrated with	New business model- new company formed for the product, turning distribution company into design and maker of professional referee equipment	Increased sale by 290% p/a with increased gross profit of 224%. Increased brand awareness and loyalty	Changing nature of a company with design-led approach of effectively combine experience of the founder and accumulated understanding of customer requirements
Key References: http://www.effectivedesign.org.uk/winners/2015/industrial-design/referee-electronic-paging-system, http://www.effectivedesign.org.uk/sites/default/files/6.2.1%20Touchline%20Flags%20.pdf, http://www.touchlineflags.com/, http://www.la-design.co.uk/portfolio/entry/h-international-electronic-referee-flags/#content								

BT Hub (B)	An update for the company's router bundle (as part of internet service) is needed	Investment by the BT for consultation with a design consulting company (external engagement)	Collaboration with various design agencies (industrial design, packaging and structural packaging) with industrial design as a core to product development	BT Home Hub 5 (with integrated VDSL) that fits in letter box without the need for engineer installation. Packaging and installation instruction	Use of web-based installation process. Emphasis on choreographed customer experience-combining hardware, software and service	n/a	Better customer experience (reduced frustration of missed delivery and engineer installation).	Design-led approach to simplify (CD-free) installation reducing service and distribution costs.
Key References: http://www.effectivedesign.org.uk/winners/2015/industrial-design/bt-home-hub-5, http://www.effectivedesign.org.uk/sites/default/files/15_05_05_Alloy_DBA_Hub5_Submission_public_portrait_15_Pg_0.pdf, http://www.thealloy.com/projects/bt-home-hub-5, http://www.thealloy.com/projects/bt-home-hub-5, http://www.trustedreviews.com/bt-home-hub-5-review								
BT Phone (A,B)	Improvement of existing range with new strategic decision made by the company in a mature market	Build-up of client (the company) and agent (design consultancy) relationship. Company commitment to use design as part of strategic decision-making	Integrated modular technology and design strategy development → Review of the product range → design identity system creation → new product development	Range of products designed and part developed with external design agency. Modular	Block nuisance calls service. Design and development process aiming elderly market where the product range	n/a	Company's fastest selling device (79% more than competitors). 19% less cost. Increased market share	Design as part of integral part (driver) in making strategic decisions through continued relationship with a design consulting firm.
Key References: http://www.effectivedesign.org.uk/winners/2014/product/bt6500-product-range, http://www.effectivedesign.org.uk/sites/default/files/6.2.1%20Alloy%20Ltd.pdf, https://blogs.which.co.uk/technology/phones-3/nuisance-calls-bt-6500-gigaset/								
Lovair (A,C)	New entry to highly competitive and saturated market	Partnership with a design innovation consultancy (Factory Design)	Identification of opportunity by the company. Collaboration with design innovation	New product range wash basins with range of solid surface materials (other	n/a	New Market exploitation with new range of product. Changed business model	Increased sales, profit margin and market share. Increased reliability	The factory design provided solution for whole manufacturing

			consultancy to create range of products that provide unique experience to the users	than stainless steel products)- bespoke and standard designs that is easy to maintain with reduced part counts		(company's own production facility- became manufacturer).		value chain from product development, setting up the first manufacturing facility and aftersales service
Key References: http://www.effectivedesign.org.uk/winners/2014/product/corporate-wash-slabs, http://www.effectivedesign.org.uk/sites/default/files/6.4.1%20Factorydesign.pdf, http://www.lovair.com/en/slabs.html, http://www.lovair.com/en/about-us.html								
GSK Consumer healthcare-environments (B)	Move to newly designed office and the company wanted to create best environment for the employees to innovate. Lack of consistent internal branding	Office staff collaboration. Strategic decision to improve working environment. Allocated budget for professional work space design (investment and commitment)	Pre-move staff survey - identify staff requirements and current level of internal branding. Identify need to communicate company vision and brand values better. External design branding agency to improve overall working environment	n/a	Environment design development identified and solidified the company's vision and values. Increased productivity through creating SMART working zones	Scalable design concept of office environments. Encourage innovation through collaboration. Improvement of office culture through	80% staff being aware of company vision (increased by one third), brand values. Increased employee pride, ability to innovate and network	Office design and internal branding for global company using design as a medium to maximise brand awareness (internal) and cultivate innovation
Key References: http://www.effectivedesign.org.uk/winners/2014/interiors-office/gsk-consumer-healthcare-office-environments, http://www.effectivedesign.org.uk/sites/default/files/7.1.1%20Radley%20Yeldar.pdf, http://workdesign.com/2014/03/work-design-now-treatment-gsk/, http://www.warc.com/Pages/Taxonomy/Marketing%20Intelligence/Agencies/Radley%20Yeldar/Results.Index?DVals=4294658463&Sort=ContentDate|1&Filter=All,								
AEG Powertools (A)	Declining sales and lack of brand presence between parent	Commitment by the VP for Global Marketing to	Working with branding agency to re-launch a brand that has	New publication materials to effectively	New brand message for existing product range to increase	Create strategic message for the brand- 'the power to lead'.	54% increase in sales value, 13% increase in sale volume	Branding exercise becoming a key driver for

	company's (TTI) other brands- faces brand extinction. Poor brand perception	use design strategy to re-brand and to save the frail brand	rich historical heritage but lost the competitiveness through increased competitors in the market	convey the brand message	impact and awareness of the brand. Use consistent branding (external and internal).	Rediscover and emphasis heritage of the brand	(between 2009-2011), 0.67% market share increase, 7,606% ROI in 2yrs	company's strategic change- much to do with internal branding and employee engagements
Key References: http://www.effectivedesign.org.uk/winners/2013/brand-identity/aeg-powertools-rebrand, http://www.effectivedesign.org.uk/sites/default/files/1.1.4%20AEG.pdf, http://www.aeg-powertools.eu/, http://www.aeg-powertools.eu/header/about-aeg/								
Lysol/Dettol No-touch hand wash - Reckitt Benckiser (B,C)	New business innovation strategy to be implanted in highly competitive market	Clear strategic direction and design specifications defined for new product development	Market research consumer testing (the company) → creation of design specification → design, development of product and consumable pack, and implementation support (Kinneir Dufort)	Battery powered no-touch hand-wash dispenser and subsequent refills. Simple components using low-cost technology	Platform technology for the product that can be used as base for future product range expansion.	n/a	5-year average sale growth of 15.1%. 8.8M device (dispenser) and 16.1M (refills) global sales in 2011 from 2010 launch	Design-led product range creating added value (increased sales, profit, brand-loyalty) and lead changes proposed in new business strategy
Key References: http://www.effectivedesign.org.uk/winners/2013/product-design/lysol-dettol-no-touch-hand-wash, http://www.effectivedesign.org.uk/sites/default/files/6.2.1%20Lysol_0.pdf, http://www.kinneirdufort.com/work/consumer/reckitt-benckiser-lysol, http://www.dettol.co.uk/products/liquid-handwash/dettol-no-touch-antibacterial-hand-wash/								
Dulux Perfect finish - ICI paints (B)	Low market share of brand's paint accessory compared to company's paint range. Saturated	Financial commitment to develop a new range of product through hiring professional design	Market opportunity identification and design outline creation (the company) → design	Triangular brush with integrated tin opener. Easy clean squeegee for roller	Design-led development process to emphasise customer experience and brand integrity	New business model- launching paint accessory market through new product launch.	5% share of market (after initial launch). 4 IP registered. Award wins and positive reviews	Design consultancy essential in identifying and addressing unmet customer

	market.	innovation agency	development, packaging and display design (external agency- Webb de Vlam)			New retail (distribution)- channels		needs through design process
Key References: http://2012.effectivedesign.org.uk/product/dulux.php, http://2012.effectivedesign.org.uk/pdf/2012/silver/6.2.1.pdf, http://www.which.co.uk/news/2009/08/dulux-launches-perfect-painting-paint-brushes-182122/								
Acro Aircraft Seating (C)	Lack of bespoke seating solution for low-cost airlines that is cost-effective without sacrificing passenger comfort	Working with design consultancy to amplify the advantages of in-house engineering solutions in simple and practical (manufacturing view point) for commercial market	Cost of ownership in mind from the early stage of design. Manufacturing process and maintenance considered to reduce parts and for easy and modular production and part replacements	Lightest in industry seating solution for low-cost airline (Jet2.com) that saves fuel 950kg/year (for typical Boeing 737) equating US$150k-200k savings for the airliner (2009)	Manufacturing process improvement (reduction) to satisfy the initial product requirements	n/a	Increase in sales and market share. International sales without any advertising. Helped make the start-up company to diversify its range of products.	A stat-up with technical ability meets design solutions to successfully launce a product to, then a niche market. Inherently, the design considers technicality of manufacturing to reduce parts used.
Key References: http://2012.effectivedesign.org.uk/product/superlight.php, http://2012.effectivedesign.org.uk/pdf/2012/gold/6.4.1.pdf, http://acro.aero/company.htm, http://www.dailymail.co.uk/travel/travel_news/article-3052132/The-economy-seats-future-Radical-designs-offer-legroom-better-sleep-end-elbow-wars-cattle-class.html, http://www.ft.com/cms/s/0/ebbbf906-c412-11e4-9019-00144feab7de.html								
Unilever-Project 'Rainbow' (B)	Use of over 100 different inks across different sub brands (Spread & Cooking Category –	Continued relationship with external design consultancy. Financial commitment	Identification of a problem in current print production system (Agency- LFH Brand Identity).	Brand print production guideline with only using six inks without compromising the look and	Print production 'audit' process added (order of importance, frequency of use, difficulty of reproduction).	n/a	Significant print production cost savings. Reduction in stock errors/write-	Colour-rich branding necessary to stand out in the competitive market.

	SCC) resulting technical complexity and high production cost	(fees etc.)	Rationalisation and specification set by the company with support from the agency.	feel of 150 sub-brands and greater consistency	Colour management guideline for all sub brands		offs. Sustainability improvement- greener, leaner solution for packaging	The brand consultancy since liquidated
Key References: http://2012.effectivedesign.org.uk/management/colour_harmony.php, http://2012.effectivedesign.org.uk/pdf/2012/silver/colour-harmonisation-project-rainbow.pdf, https://www.thegazette.co.uk/notice/2312153								
Queen's Award for Enterprise (Innovation) winners								
Ancon Building Products (B)	Complicated formwork and the additional materials used to construct a support corbel	Rich technical know-hows and experiences in the market. Commitment to innovation from the top-level managers	n/a	Ground-breaking lockable dowel used in post-tensioned concrete buildings	n/a	n/a	Increased sales and export in short period	The product accelerates the speed of construction, reduces build costs, simplifies concrete design, improves aesthetics and enhances on-site safety.
Key References: http://queensawardsmagazine.com/business-winner/ancon-ltd/, http://www.ancon.co.uk/, http://www.ancon.co.uk/what-s-new/ancon-wins-queens-award-for-enterprise-in-innovation, http://companycheck.co.uk/company/00210138/ANCON-LIMITED/group-structure								
Aspen Pumps Ltd (A)	Designing & producing products focusing reliability, performance and ease of installation	The application of in-house engineering knowledge and experience in to product development	In-house knowledge, specific market needs identification, customer feedback oriented product	Mini Pump range that offers solutions that are designed to be simple to install and	The production facilities run using lean manufacturing principles and with focus on repeatability	n/a	Not directly, but involved in securing £105 million investment from 3i	Identified the need of easy to install pumps for condensation removal pumps for air-conditioners

			development, and localised training (for the engineers)					
Key References: http://queensawardsmagazine.com/business-winner/aspen-pumps-limited-2/, http://www.aspenpumps.com/, http://companycheck.co.uk/company/08291827/ASPEN-PUMPS-LIMITED, http://www.3i.com/news/corporate-news/3i-invests-aspen-pumps-%C2%A3105-million-transaction								
Aurox Ltd (A)	Providing an instrument which is small and inexpensive enough to be attached to a conventional microscope	Collaboration with microscope manufacturer (Carl Zeiss) and CCD camera (Andor plc)	Rediscovering the real basic physics of how a microscope forms an image (deconstructing the conventions)	Creating inexpensive 3d microscopic imaging instrument (SD62- confocal microscopy) to be used in a lab,	Spinout from ISIS innovation from Oxford University. Add functionality to already existing microscopes	n/a	Success of SD62 being a stepping stone for product range extension	Central imaging facility normally has big, expensive microscopes that requires maintenance
Key References: http://queensawardsmagazine.com/business-winner/aurox-limited/, http://www.aurox.co.uk/, http://isis-innovation.com/queens-award-isis-spin-aurox-ltd/, https://www.youtube.com/watch?v=OIm0m45NUmU&feature=youtu.be&utm_source=Lab+Bulletin+Weekly+Updates&utm_campaign=e8a35aa908-Lab_Bulletin_Weekly_Update_new_11_3_2012&utm_medium=email								
Centek Limited (A)	Centralisation failure is one of the biggest causes of downtime in the oil industry- costing up to $1million a day.	Time, investment getting engineers and sales people going out to the field talking to the customers to find exactly what they did want with continuing improvements	Initially, the company had to change people's concept of the importance of centralisation	Centek UROS Centraliser: device that enables deep boreholes to be drilled effectively	Using lean manufacturing principles in production and with focus on repeatability. Undertake most rigorous quality control within the industry - full traceability	n/a	Became an international industry leader	Centek is a world leader in designing and manufacturing bow spring centralisers which are used by the oil and gas industries in the drilling process to keep casing centred
Key References: http://www.queensawardsmagazine.com/awardwinners/centek-limited, http://www.centekgroup.com/about-us/, https://www.youtube.com/watch?v=JTg_F4FZdoM#t=63, http://companycheck.co.uk/company/04216648/CENTEK-LIMITED/company-summary								

Hadley Industries Plc (B)	Continued development of steel manufacturing process has identified new ways to increase harden steel during rollforming stage	Commitment to the R&D for products and process.	The company provides total process consisting: design consulting- Tooling design- tooling manufacture- tooling commission- customer sample approval- project sign off with optional Hadley group manufacturing.	New range of cold rolled steel using patented UltraSTEEL manufacturing process.	UltraSTEEL process which work hardens metal during the rollforming process typically improving thermal, fire retardant and screw retention and achieving same strength of heavier gauges.	Privately owned company with emphasis on providing 'total' service provider with partnership approach to actively encourage and challenge customers requirement to find best and most effective solutions	New exports of over £44 million in four years with savings to customers of over £4 million (by using fewer raw materials)	UtraSTEEL (framing products) is being used in the Masdar City (Abu Dhabi's purpose built green city)
Key References: http://www.queensawardsmagazine.com/awardwinners/hadley-industries-plc, http://www.hadleygroup.com/news/queen%E2%80%99s-award-for-enterprise-innovation-2014.aspx								
Heat Trace Ltd (B,C)	Heat Trace is a specialist in designing and manufacturing trace heating solutions for a wide range of applications and industries including oil & gas, petrochemical, food processing and power generation, etc	Investment (10-15% of revenue) on R&D- higher than competitors. In-house training, site installation training. On-going commitment to set and improve standards	Engineering Group takes the design criteria, and produces an optimised temperature-safe technical and commercial design to provide the most energy efficient and cost effective solution. Proven engineering provides the	Highest temperature self-regulating heat tracer (2003) Worlds first 300 degrees C self-regulating tracer (2010) World's first sub-sea electrically heat traced, reeled Pipe-In-Pipe System (2011) Turnkey solution	n/a	Professional management directing a skilled, multi-disciplined project group. Program control, cost, quality and safety as integral parts of project management. Emphasis on research based development of products	Strong innovation culture with number of industry first products throughout the history of the company. Over 20 patent applications under review (2012)	Investment on R&D and regular update of the main products provides Heat Trace a largest range of heating cables in the world - competitive advantage

			most efficient, trouble-free and cost effective Heat Tracing solutions available					
Key References: http://www.queensawardsmagazine.com/awardwinners/heat-trace-ltd, http://www.heat-trace.com/, http://www.heat-trace.com/admin/news/77_Heat%20Trace%20Limited%20-%20DK-27Nov2014%20Press%20Release%20(3).pdf, http://www.heat-trace.co.uk/Company/Innovation_-_A_Brief_History, http://www.heat-trace.co.uk/Services/Design__Engineering_Services, http://www.heat-trace.co.uk/Company/Company_Profile								
Irisys - the trading name of Infrared Integrated Systems Ltd (B,C)	Extensive research proves that queuing at the checkout is the number one cause of customer dissatisfaction in retailing. Conversely, , has become a business imperative.	Original technology (Infrared camera)	Founded in 1996 by scientist and engineers from Plessey Caswell research lab (high resolution military infrared imaging systems originally aimed to use for commercial fire and security market but realised potential in counting people in retail	Gaxelle DualView Gazelle Thermal Queue management system.	Infrared camera technology originally developed for military but with high cost. Reduction in image quality to bring down the manufacturing cost	Understanding that most major retailers, led by the supermarket chains, are now investing in queue management (QM) solutions, the business model has changed from targeting military to retail sector and also provides consulting in QM	80% of products are exported. Short queues – build customer loyalty and encourage spending. Reducing queuing and making more effective use of checkout staff and customer service representatives	Making technology cheaper and applying it to somewhere else. In 2012 became part of Fluke corporation
Key References: http://www.queensawardsmagazine.com/awardwinners/irisys-the-trading-name-of-infrared-integrated-systems-ltd, http://www.irisys.net/about-us, https://www.linkedin.com/company/irisys, https://en.wikipedia.org/wiki/Irisys								
Limbs & Things (B)	Use of patients for the initial training of doctors and nurses was	Extensive experience of the owner (Medical Artist), Margot	Innovation is key to the progress and success of the company and its	Accurate, high quality, realistic simulators for physical examination	Knowing what the customer needs drives the company. Understanding the	Continue to work closely with leading clinicians and customers,	£12m turnover Expanding export market. Accumulated understanding	Identifying the market change (medical education) and subsequent

	neither ethical nor cost effective. There is a constant battle to produce robust representations of human tissue without the loss of fidelity. Many of the design challenges that we face are overcome by exploiting the unique properties of rubbers, foams and textiles.	Cooper. Clear company goal: to enable initial 'hands-on' skills training of Healthcare Professionals on models made from non-biological materials, thus moving the trainees away from patients and the increasingly litigious environment of the operating rooms.	products: the initial focus was to make a realistic representation of human skin to be used in the training of suturing techniques. The company leads the national and international market in manufacture of training models and simulators for paramedics, nurses, doctors and specialists.	and procedural skills, anatomical models and multimedia education materials. Confidential design & build service for industry and corporate clients.	course content in medical training - be on the steering group of the courses run by the medical colleges. Combining traditional hand sculpting with the latest CAD technology to achieve simple and precise products.	exploring new technologies and materials and promoting products within a worldwide marketplace.	of the unique properties of rubbers, foams and textiles	opportunities. Extensive collaboration with medical institution (Southmead Hospital-Bristol), clients (medical professionals), Government (UKTI, Business Growth Service (former MAS)), employees
Key References: http://www.queensawardsmagazine.com/awardwinners/limbs-things, http://www.limbsandthings.com/uk/about, http://www.mas.businessgrowthservice.greatbusiness.gov.uk/news/bristol-company-limbs-and-things-joins-national-campaign/, http://www.greatbusiness.gov.uk/a-very-different-silicon-revolution/								
Linn Products Limited (B,C)	Weakness in communication (consistency and effectiveness) of strategy	£1.97m investment in R&D - rolled out Exakt audio	Business Review (Diagnostic with FutureSME) with MD and director of manufacturing and widened with the whole management team	Sondek LP12 Exakt Kiko Linn Recording Space Opimisation	Monthly review, with significant changes every 6 months. Take feedback and questions from everybody in the company	Visual Strategy-communicate strategic intent to all employees-everyone in the company has a context for understanding why we are doing what we are doing	2008-2014 Sixth continuous year of profitability with growing revenue £19.2m turnover, £1.69m pre-tax profit	Adapted quickly to the new age of digital music. New business model of integrating Linn Studio has been successful (2010) and expanding range with

								Kiko.
Key References: http://www.queensawardsmagazine.com/awardwinners/linn-products-limited, http://www.linn.co.uk/, http://www.futuresme.eu/docs/case-studies/linn-a3.pdf?sfvrsn=2, https://www.youtube.com/watch?v=8gb7hON6waU, https://www.youtube.com/watch?v=sxLWp0PYXGg, https://www.youtube.com/watch?v=bairi2SbTO0, http://www.heraldscotland.com/business/13188893.Profits_up_as_Linn_continues_its_quest_for_sonic_perfection/								
MILMEGA Ltd (B,C)	Incremental and continuous improvements are required to keep the company ahead of competition from overseas.	MD's commitment to be different while maintaining a reputation for high quality and customer service	Aims to take the complexity out of amplifier ownership with high quality and reliability. This is combined with first class technical specifications and a responsiveness for customers	High power RF and microwave amplifiers using gallium nitride-based transistors	Application of unique design methodology in product development process	n/a	Continued growth over 5 years with 90% of sales in exports	The company is acquired by Teseq Ltd (Swiss company) and became responsible for amplifier design and manufacture within the group
Key References: http://www.queensawardsmagazine.com/awardwinners/milmega-ltd, http://www.milmega.co.uk/downloads/PresentationPressrelease84.pdf, http://www.milmega.co.uk/about_milmega.php, https://en.wikipedia.org/wiki/MILMEGA								
NanoSight Ltd (C)	The founder (Bob Carr) invented a technology that can provide high-resolution analysis of particle distribution	Commitment to develop and materialise original technology to commercially viable solution by founders (Bob Carr and John Knowles)	Developing the technique of patented Nanoparticle Tracking Analysis (NTA) Production of series of instruments to count, size and visualize nanoparticles in liquid suspension using NTA	Range of scientific instruments to detect and visualise nanoparticles with 'Nanoparticle Tracking Analysis (NTA)'	The NTA process combines laser light scattering microscopy with a charge-coupled device (CCD) or a scientific complementary metal-oxide-semiconductor (sCMOS) camera	n/a	Rapid adoption of NTA in global pharmaceutical companies (GSK, Pfizer etc.), respected research institutions (FDA etc.) and universities. Annual sales growth of 60% since 2005	Acquired by Malvern Instruments in 2013 and only a product range bears the name 'NanoSight'

Key References: http://www.queensawardsmagazine.com/awardwinners/nanosight-ltd, http://www.labmate-online.com/news/news-and-views/5/nanosight_ltd/queens_award_for_nanosight/25273/, http://www.malvern.com/en/products/product-range/nanosight-range/default.aspx, http://www.fast50.co.uk/2014-winners/previous-winners.aspx								
Russell IPM Ltd (A,C)	Infestations of the devastating and destructive tomato pest, Tuta absoluta needed to be controlled.	Company commitment to research and continuous development of high potential new products	In-house R & D. Continuous problem identification. Provision of customer focused solution (bespoke or standard) to the issues facing pest controllers	Pest management products (Ferolite) designed to attract the insect to the trap in order to achieve the maximum trap catch of the adult population	n/a	n/a	Market leader in the market. Strong international sales	Discovery of the light wavelength that Tuta absoluta is most attracted to was key in creating the award winning product
Key References: http://www.queensawardsmagazine.com/awardwinners/russell-ipm-ltd, http://www.russellipm.com/about-us/, http://www.freshplaza.com/article/133269/Russell-IPM-develops-solution-against-fruit-flies, http://www.xlure-traps.com/								
SELEX Galileo (B)	Highly technical market requires the company to continue research and development	15% of revenues being invested back into research and development	Combining state-of-the-art technology, integration and modification capability, training, and logistics support, the company supply an inclusive service loop that addresses customers' stated requirements	Vixenm Seaspray, InfraRed Counter Measures and Laser capabilities	Continued investment in R&D to ensure company's radar technology is market leading in highly advanced and technical market	Identify and emphasise strategic driver (providing systems for the Eurofighter Typhoon) enabled increased international competitiveness	Increased overseas revenues by 48% in 3 years, exporting 60% of its production	SELEX Galileo Inc. is subsidiary of Finmeccanica. Leveraging a distinctive strength in airborne mission-critical systems for situational awareness, self-protection, and surveillance
Key References: http://www.queensawardsmagazine.com/awardwinners/selex-galileo, http://www.selexgalileo.com/capabilities, http://www.ainonline.com/aviation-news/defense/2012-07-08/selex-galileo-leads-europes-e-scan-drive, http://optics.org/news/2/6/26								

Harrison Spinks Limited (A)	Luxury bed manufacturer pushing its innovation to obtain competitive advantage and increased international sales	Vertically integrated company culture	Continuously pushing boundaries and thinking outside the box.	High Density spring and the Revolution spring-delivering enhanced technical performance and increased efficiency	Use of spring production process to be applied to other industry that require spring (e.g. car manufacturers)	Business model expansion with same process and similar products (spring system)	Increased international sales of springs and to other manufacturers (in different sectors)	Component production originally for the company's final product (B2C) becoming additional saleable product (B2B)
Key References: http://www.queensawardsmagazine.com/awardwinners/harrison-spinks-limited, http://www.harrisonspinks.co.uk/story#comfort-from-technology, http://www.telegraph.co.uk/business/2016/04/21/britains-brightest-businesses-named-in-queens-awards/, http://www.furniturenews.net/news/articles/2014/07/2110793982-harrison-spinks-wins-innovation-manufacturing-award								
Stage One Creative Services Ltd (B)	Bespoke challenges for every projects as the company provides scenic and engineering (manufacturing) solutions for their 'clients'	Continued emphasis on innovation both in technological and process to seek best ways to 'solve' clients' challenges	Collaboration of creative, design-led problem solving with technical know-how and abundant experience as one unit for every projects-solving problems of the clients to enable realisation of their imagination	Thomas Heatherwick's 2012 Olympic Cauldron. Zaha Hadid's Chanel Mobile Art Pavilion. Serpentine Gallery Pavilions	New production process fit for each project-flexible while effectively using the latest tools (3d printers, Poseidon 5-axis CNC etc.) to ensure efficiency in production	Work environment with both horizontal (departmental) and vertical (positional) collaborations. Emphasis on innovation from the top management	Global recognition and positive relationship with the clients.	Creativity and problem solving is embedded in the company (innovation DNA) as the business is positioned to be a partner and solution provider for highly creative designers, artists and architects
Key References: http://www.queensawardsmagazine.com/awardwinners/stage-one-creative-services-ltd, http://www.stageone.co.uk/news/ http://www.yorkpress.co.uk/news/12867759.Memorial_to_mark_the_70th_anniversary_of_Tockwith_bomber_crash/								
Stanhope Seta Ltd (B)	Past measurement techniques for H2S (dangerous	nearly six years of development activity and industry testing.	Collaboration with key industry bodies inc. Lloyds	ground breaking approach to the measurement of H2S in liquid	In-house R&D. Successful implementation of six-sigma and lean	n/a	80% of the products are exported to over 120	Leading the field of quality control testing. Strong

	gas) is basic with long preparation times and gave inconsistent results.	Enthusiastic energetic support from MDs	Register and FOBAS	Marine Fuels	manufacturing extensively in manufacturing facility		countries	relationships with customers across the world – increasing international trade
Key References: http://www.stanhope-seta.co.uk/about_us.asp, http://www.queensawardsmagazine.com/awardwinners/stanhope-seta-ltd								
Survitec Group: RFD Beaufort Ltd (B)	Changes in regulations, vessel designs and increased passenger capacity requires the company to innovate	The company has continued to invest in the continuous development of the product.	Works closely with Invest Northern Ireland, securing research and development grants to help bring the product to market	RFD MarinArk- marine survival equipment- capable of evacuating over 800 people in less than 30 minutes	Continuous quality assurance accordance to ISO 9001 procedures, regulations and advances in vessel design	n/a	Export sales increase of 35%. Winning MX Award for 'Most Improved Business' (2011)	Long history (since 1920) of developing and manufacturing marine survival equipment. Incremental innovation with the products
Key References: http://www.queensawardsmagazine.com/awardwinners/survitec-group-rfd-beaufort-ltd, http://rfdbeaufort.com/rfdBeaufort/rfd_Commercial/about, https://workspace.imperial.ac.uk/ref/Public/UoA%2009%20-%20Physics/P3%20-%20Aurox/2012_QA_Winners.pdf/, http://survitecgroup.com/news/survitec-awarded-queen-s-award-for-enterprise								
Tangle Teezer Limited (C)	Tangled hair creating painful knots while brushing the hair	Commitment of inventor and entrepreneur Shaun Pulfrey to commercialise his invention to the market	Eureka moment turned into commercial production and marketing challenge.	Range of Tangle Teezer brushed that gently detangle hair, effortlessly and painlessly	Combining patented bristle design, advanced plastics technology and a professional understanding of how to detangle hair.	n/a	10 million product sold in over 80 countries (2014)- 10 sold every minute. 80% export and double revenue	Demonstration of inventor determination to sell his product in the market (appeared in the Dragon's Den boosted the brand

							growth every year	recognition
Key References: http://www.queensawardsmagazine.com/awardwinners/tangle-teezer-limited, http://startups.co.uk/dragons-den-success-stories-tangle-teezer/, http://www.dailymail.co.uk/video/news/video-1198118/Innovative-Tangle-Teezer-blow-drying-brush-hugely-popular.html, https://www.tangleteezer.com/made-in-great-britain.php, https://www.gov.uk/government/case-studies/tangle-teezer-sells-overseas-with-ukti-support								
Tenmat Limited (A,B)	Continued improvements in fire and life safety standards for both buildings and their occupants providing both problem and opportunity for the company	Heavy investment in R&D. In-house technical resources with separate product testing facility	Working closely with the company's business partners and building safety specifiers- ensuring the product development fulfils current and future requirements	Range of passive fire protection products- proven to improve fire and life safety standards for both buildings and their occupants.	n/a	n/a	80% export. 20% export sales growth YoY (between 2010-2013). Leading the market in Europe and North America	The company's unique ability to form complex shapes and control the expansion direction which adds to the product performance
Key References: http://www.queensawardsmagazine.com/awardwinners/tenmat-limited, http://www.tenmat.com/Content/About%20us, http://www.fwi.co.uk/machinery/tougher-than-tungsten-material-could-reduce-farm-kit-wear.htm, http://www.manchestereveningnews.co.uk/business/business-news/north-west-companies-awarded-queens-2989812								
Track Analysis Systems Ltd (A,B)	Application (product realisation) of automatic image analysis system for radon and neutron dosimetry measurement	Core technology of the product range developed by the founder.	Continued Research and development in improving the quality of product	TASTRAK (PADC) track etch radiation detectors and RADOSURE radon dosimeters.	n/a	n/a	Market leader with patented technology and subsequent product range	Highly specialised product- however, the company is expanding the market through identifying the product advantages
Key References: http://www.queensawardsmagazine.com/awardwinners/track-analysis-systems-ltd, http://www.tasl.co.uk/about.php, http://www.bristol.ac.uk/red/research-commercial/uobcompanies/track.html								

Zeeko Ltd (B)	Development of unique polishing technique through collaboration between the company and university (University College London)	Company's commitment to innovation and agility to overcome the challenges presented by the research team and/or the clients	Parallel development of the hardware (IRP) and software to	Intelligent Robotic Polishers (IRP)- ultra precision polishing machines to nanometre accuracy	Knowledge management through utilising experience of overcoming challenge, working closely with the clients. 52 worldwide patents	Innovative business model- clear understanding of the market, customer challenges, problems with current solution. Strategic plan to grow laterally across sector	Double turnover every year since 2000 (to 2013). Expanding application of the products. Bespoke solution to suit niche global market	Technology based company with commitment from the MD (who won the business executive of the year 2012)
Key References: http://www.queensawardsmagazine.com/awardwinners/zeeko-ltd, http://spie.org/newsroom/4794-faster-production-of-high-quality-telescope-mirrors?ArticleID=x93597, http://www.zeeko.co.uk/site/tiki-index.php?page=HomePagePublic, http://www.midlandsbusinessnews.co.uk/polishing-machine-manufacturer-wins-two-business-awards-in-one-night/								
TMMX Awards								
Xtrac (A,C)	Highly specialised transmission needed in the motor sports industry (F1, LeMans, Dakar Rally etc.)	Top management commitment to create better work environment and supporting of the staffs and innovation culture in product, process and the business	Special facilities to develop and engage with the client from the start of development. Constant push for break technology boundary and manufacturing techniques	Transmissions for moto racing that has been used by top three teams in Dakar Rally, Le Mans and F1s	Efficient manufacturing process integrating the skills of designers and engineers. High utilisation of CAD system which directly connect design/engineering to manufacturing	Employee trust chair scheme- employees forming largest shareholder- promoting a 'family culture' within the company	Fast flexible response to changes in technology and bespoke customer demands. Multi award wins for products and management practice	Every head of transmissions at F1 teams is an ex-Xtrac employees (2015)
Key References: http://www.xtrac.com/index.php, http://www.themanufacturer.com/articles/xtrac-pole-position/, https://www.youtube.com/watch?v=h8GSDFYt2zg, http://www.eurekamagazine.co.uk/design-engineering-features/interviews/interview-with-peter-digby-xtrac/57697/								

Pryor Marking Technology (A)	Rapidly changing market demand for more advanced technique in marking and tracing	Customer centric organisation with support to integrate experience, engineering excellence and company vision	Pushing the boundary to be forefront of manufacturing technology to provide best solutions for the clients	Single source provider of range of products ranging from simple hand stamp through to turnkey, bespoke designed systems with multi-axis computer-controlled marking heads	Integration of service with products providing best possible customer ownership experience. Provides machine vision and traceability software	n/a	Pryor Marking Technology designs and manufactures the widest range of permanent marking systems in the world, together with software and barcode readers for component tracking and tracing	Manufacturer of both traditional and innovative marking solutions.
Key References: http://www.pryormarking.com/, https://www.youtube.com/watch?v=MkWfPjLlA28, www.themanufacturermxawards.com/#!winners/qonzo, http://www.pryormarking.com/about-values, http://www.pryormarking.com/downloads/downloadFile/3								
Rayovac MicroPower Division (A)	Hearing aid batteries with improved power, reliability and lifespan needed	Continued investment in product development and new technology	Continued collaboration with hard of hearing community to ensure the product meets the changing market demands	Long-lasting hearing aid batteries. Innovative packaging design	n/a	n/a	"World's number one selling hearing aid battery"	New production line opened by HRH The Duke of Kent at Washington (UK) factory.
Key References: https://www.necc.co.uk/uploads/files/PIFbF2cHUJCCjcj8.pdf, http://www.rayovac.eu/uk/about-us-overview, http://www.hearingreview.com/2012/04/rayovac-receives-uks-queens-award-for-second-consecutive-year/, http://www.rayovac.eu/assets/releases/38.pdf								

APPENDIX D: Questions for Manufacturing Expert (ME) Interviews

Ice-breaking questions

Do you produce all your products in the UK, including those you sell overseas?
What are the main markets for your products? (UK? Overseas?)

Current competitive strength of the company

Q1: In your opinion, what is the current competitive strength of the company?

Manufacturing in the UK

Q2: What are the main advantages and disadvantages of UK-based manufacturing?
Q3: Do you recognise greater competition within the UK, or from overseas?

Innovative manufacturing, Innovation and technology in manufacturing companies

Q4: What is your (instinctive) definition of 'innovative manufacturing'?
Q5: What would be recognised as innovative activities in your company? – This will determine whether the interviewee's opinion of innovation is technology-, process- or creativity-driven.

Design in manufacturing

Q6: What are the functions of design in your company? (Discussion of 'design' activities of the company)
Q7: What, in your opinion, is the relationship between design investment and the overall performance (growth, sales increase, market share rise) of the company?
Q8: Can you give an example where using 'good' design has increased your company's performance?
Q9: Do you see design as a strategic tool for the business or just a part of the process of producing a desired outcome?

Identification of design innovation characteristics

(N.B. If design innovation actions and its effects have not been discussed in previous questions, ask this question)

Q10: How do you think ‘design’ can increase/cultivate innovation in manufacturing companies?

Design, and collaboration and the government support

Q11: Do you conduct collaborative work with other institutions? (e.g. government, universities, other companies, etc) If so, what is the purpose of the collaboration?

Q12: What form of support do you think could benefit further development of innovation and design in your company?

APPENDIX E: Questions for Design Innovation Expert (DE) Interviews

Preparation:

- Design Spectrum Model
- Design Innovation Spectrum Model

Brief introduction to the research:

The research I am conducting considers how to enhance innovativeness of manufacturing companies through design. Design here takes on a broader meaning, covering both actions to produce a product and a way of thinking for the management of a company as a whole.

Background - interviewee specific

[Prior research of the company (or individual) is required and questions should be asked about the main work they undertake for manufacturing companies in the UK. For an organisation, ask about prior research on the organisation's activities and ask about the broader acceptance of value of design in manufacturing companies.]

Design Spectrum

The design spectrum model shows the expanding spectrum of design in a company.

(Present the Design Spectrum model)

Design Spectrum

	Designing (Product/Production/Communication/Service)	Design Strategy (Managing Design)	Corporate-level Design Thinking (Managing Company)
Business level	Activities (Operational) Level	Strategic Level	Organisational Level
Creation of	Artefacts Image/Service	Process	System
Design Practitioner/ Decision-Maker	Professional Designer Engineering Designer Engineer	Design Manager Senior Manager	Director CEO Board of Directors Policy Maker
Influence of Design in... (Designing for)	Manufacturing/Assembly Form/Function Product Service User Experience	Design Process Design Implementation	Company Culture Business Model Design Policy Vision/Strategy
Required Understanding in...	Trend Production Process New Technology/Material User Behaviour Market Environment	Design Process Value of Design Strategic Management	Corporate Strategy Design Thinking Business Policy
Underlying Competence	Design Research and Development		
Design Attribute	Creative Idea Generation Experimental Problem Solving	Empathic, User-Centred Approach	Chaos to Order Communication Systems Thinking Holistic Thinking
Benefit	Product Reliability/Quality Reduce Production Cost New Product Creation Increased Revenue Service Quality Enhance Company Image New Service Creation	Attract Investment Improve Quality of Design Effectiveness of Design	Opening New Market Creative Internal Culture Increased Competitiveness Design-led Innovation Systematic Design Support Creative Business

Q1: Do you think this design spectrum model is comprehensive for innovative manufacturing companies?

Q2: Do you think the recent development of ‘design thinking’ for management should be regarded as part of the design spectrum?

Q3: The term ‘design thinking’ is used in management - do you see the benefit of this, and if so how?

Q4: What is the most effective way(s) of making companies understand the expanding value of design? And, in your opinion, how can use of the wider spectrum of design be encouraged?

Q5a: How would a company increase its capability in each area of the spectrum?

Designing:

Design Strategy:

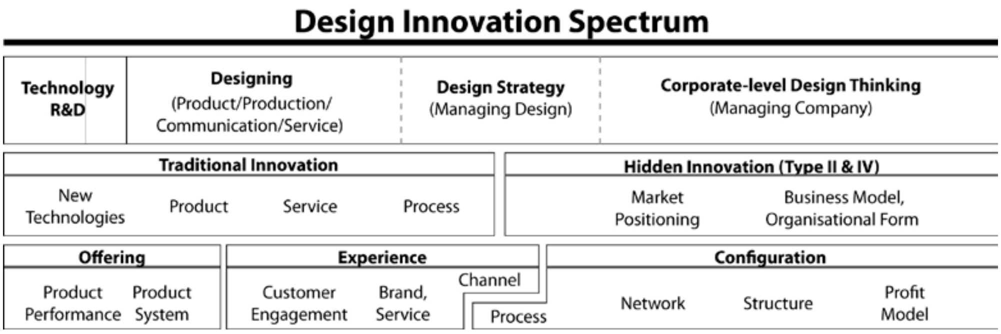
Corporate-level Design Thinking:

Q5b: Have you conducted a project where you have changed the whole company culture towards becoming more creative? Please explain how you have achieved this?

Design for innovation

This research has found that innovation has many types (referring to ’10 types of innovation’ by Keeley et al and NESTA’s ‘total innovation’) and the influence of design spans most of these innovation types.

(Present the Design Innovation Model)



Q6: Do you think this model is a good representation of the relationship between design and innovation?

Q7: Can you think of other ways design can influence innovation in manufacturing companies?

Q8: What do you think is the most important aspect of the relationship between design and innovation?

Q9: Which aspects of the Design Innovation model do you think current UK manufacturing firms need to adopt to enhance innovation capabilities?

Design Innovation Characteristics

(N.B. If design innovation actions and their effects are not discussed in previous questions, ask this question)

Q10: How do you think ‘design’ can increase/cultivate innovation in manufacturing companies?

Design challenges

Q11. What are the most common barriers to convincing the company about the value of design?

(What is the most difficult challenge of working with the manufacturing company?)

Q12. How did you overcome the challenge?

APPENDIX F: Questions for Evaluation with Manufacturing and Design Experts (EE) Interviews

Preparation:

Design Innovation Framework booklet (beta version)- SEE APPENDIX G

Introduction:

The purpose of the interview is to evaluate the Design Innovation Framework and its proposed implementation process which was developed through the research.

The research aims to create a design innovation framework to provide a systematic and comprehensive overview of expanding design innovation characteristics, and subsequent guidelines for UK innovative manufacturing companies to maximise innovativeness through design in order to enhance competitiveness. The purpose of the Design Innovation Framework is to provide a holistic overview of design innovation benefits for innovative manufacturing companies in the UK. It is designed to be used as a guide to identify and further improve technological, product/service, process and organisational innovation of a company by utilising designing, design strategy, and corporate-level design thinking which are part of the Design Innovation Spectrum.

(N.B. The questions are designed to evaluate the DIF by identifying each section's Acceptability, Potential Usefulness, Comprehensiveness, and Ease of use/understanding. If these are not discussed in the following questions, ask these questions directly).

Ice-breaking (background)- interviewee specific

[Prior research of the company (or individual) is required and questions should be asked about the main work they do for UK manufacturing companies.]

Design Innovation Framework Overview

Q1: Could you comment on the initial feel of the framework?

Q2: Do you agree with the contents and the relationships between the elements of the framework?

Q3: Can you see anything obvious missing from the framework?

Design Innovation Framework Details

Q4: Do you agree with the design innovation characteristics represented in the framework detail?

Q5: Are the Design innovation characteristics agreeable? And are they easy to understand (as a professional practitioner)?

Q6: Is there anything you would add or delete from the DIF detail?

Design Innovation Framework Implementation - before discussing the process

Q7a: Do you think the DIF is useful to help a manufacturing company improve its innovativeness?

Q7b: If so how?

Q7c: If not, how would you improve the framework to make it more useful in helping the manufacturing companies to improve innovativeness?

Q8: As a professional practitioner, how would you use the framework?

Design Innovation Framework Implementation Process

Q9: Do you think the generalised process is useful for a manufacturing company and design innovation professional such as yourself?

Q10: Do you agree with the scenarios proposed in the implementation process? Are they realistic?

Q11: Is the DIF implementation scenario practical in a real-world situation? Please share any occasion(s) where the framework might have been useful in your practice.

Overview of the Design Innovation Framework

Q12a: Do you think a manufacturing company would be willing to adopt the DIF to improve its innovativeness?

Q12b: If so, how?

Q12c: If not, what improvements could be made to ensure easier adoption by manufacturing companies (and/or design innovation professionals)?

APPENDIX G:

Design Innovation Framework booklet (beta version for evaluation)

Design Innovation Framework

Brunel University London |

Version 13_beta for evaluation

List of Contents

Introduction to Design Innovation Framework

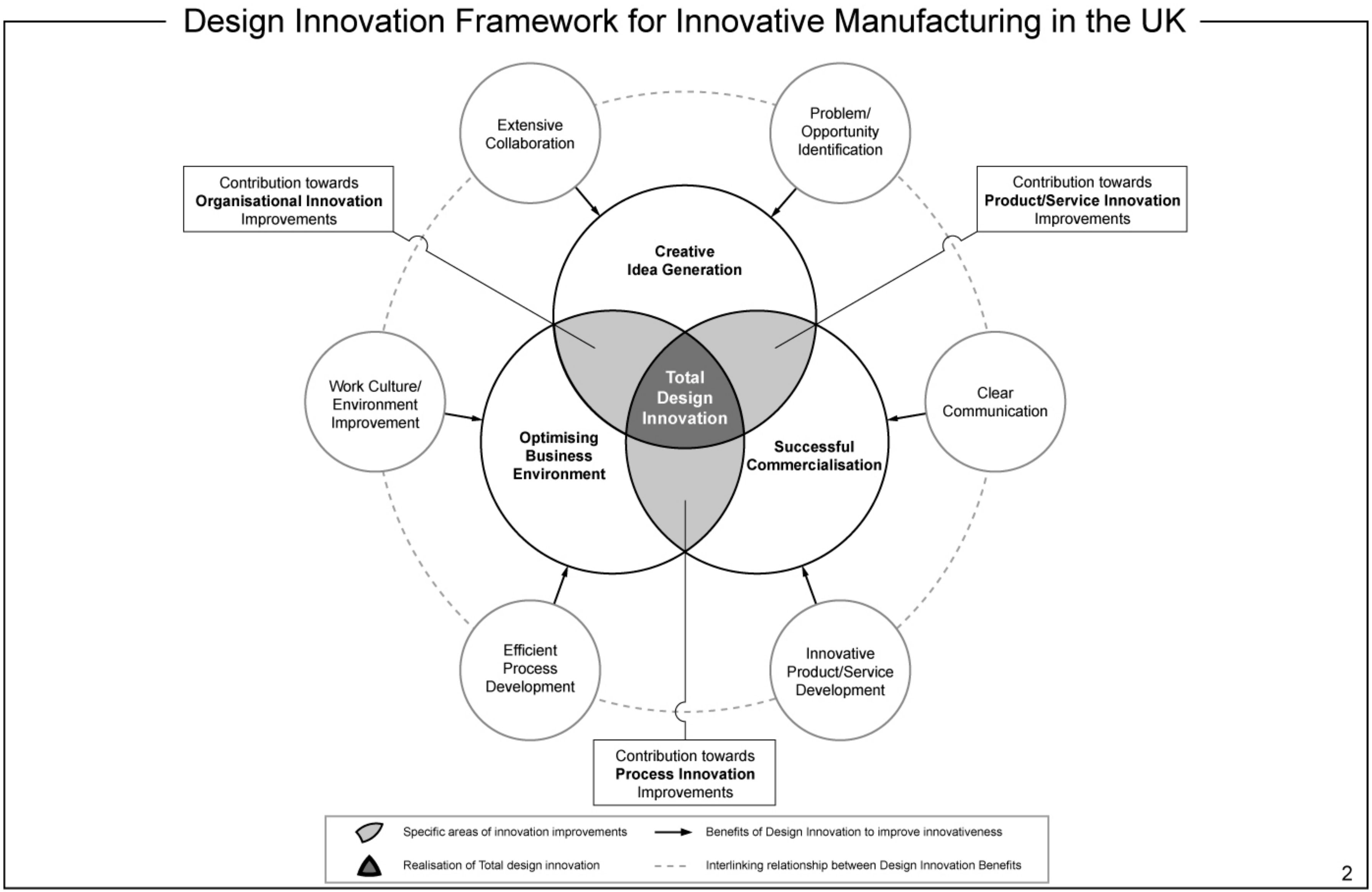
The purpose of Design Innovation Framework is to provide a holistic overview of design innovation[1] benefits for innovative manufacturing companies[2] in the UK. It is designed to be used as a guide to identify and further improve technological, product/service, process and organisational innovation of a company by utilising designing, design strategy, and corporate-level design thinking which are part of the Design Innovation Spectrum[3].

The framework includes 20 characteristics of design innovation which lead to 6 essential benefits for manufacturing companies in order to achieve 3 main goals to improve innovativeness. The Design Innovation characteristics span across the Design Innovation Spectrum, where they help identify design innovation within a company including the influences of design (output) as well as the requirements for design (input). The subsequent six benefits of design innovation are identified from the characteristics which provide improvements that a company can expect by using good design innovation practices. These benefits will help the company to achieve optimisation of business environment, generation of creative ideas, and successful commercialisation. Combinations of these areas will deliver product/service, process and organisational innovation improvements and ultimately enable the company to become a practitioner of 'total design innovation' that will increase their global competitiveness.

1 Design Innovation in this research is defined as a creative process and its outcome that enable increased innovativeness of a company through utilisation of full spectrum of design including designing (action to create product/service), design strategy (management of design process), and corporate-level design thinking (philosophy and method of design applied to managing business as a whole). Therefore, the outcome of design innovation can be radical and/or incremental changes in product, service, process, organisational culture, and/or business model.

2 Innovative Manufacturing Company is defined as a commercial organisations within manufacturing sector which recognises the importance of innovation by continuously introducing new or improved products/services, improving production processes, actively seeking for a new market, collaborating with external organisations such as universities, improving ways of working, and/or winning innovation prize(s). The research identified that the innovative manufacturing to be an enabler for advanced manufacturing to expand into high-value manufacturing, however, also a catalyst for other manufacturing companies to increase their competitiveness in the global market.

3 Design Innovation Spectrum is created by thorough literature reviews, and interviews with industry experts both in design and manufacturing fields. It illustrates extensive areas of design and innovation and their relationship. The identified areas are heavily interlinked and hence difficult to separate, however the main areas of 'design' include designing, design strategy, corporate design thinking, and 'innovation' areas include technological, product/service/process and organisational innovation (please see page 16).


Design Innovation Framework for Innovative Manufacturing in the UK
Extensive Collaboration
Problem/ Opportunity Identification
Contribution towards Organisational Innovation Improvements
Contribution towards Product/Service Innovation Improvements
Creative Idea Generation
Work Culture/ Environment Improvement
Total Design Innovation
Clear Communication
Optimising Business Environment
Successful Commercialisation
Efficient Process Development
Innovative Product/Service Development
Contribution towards Process Innovation Improvements
Specific areas of innovation improvements
Benefits of Design Innovation to improve innovativeness
Realisation of Total design innovation
Interlinking relationship between Design Innovation Benefits
2

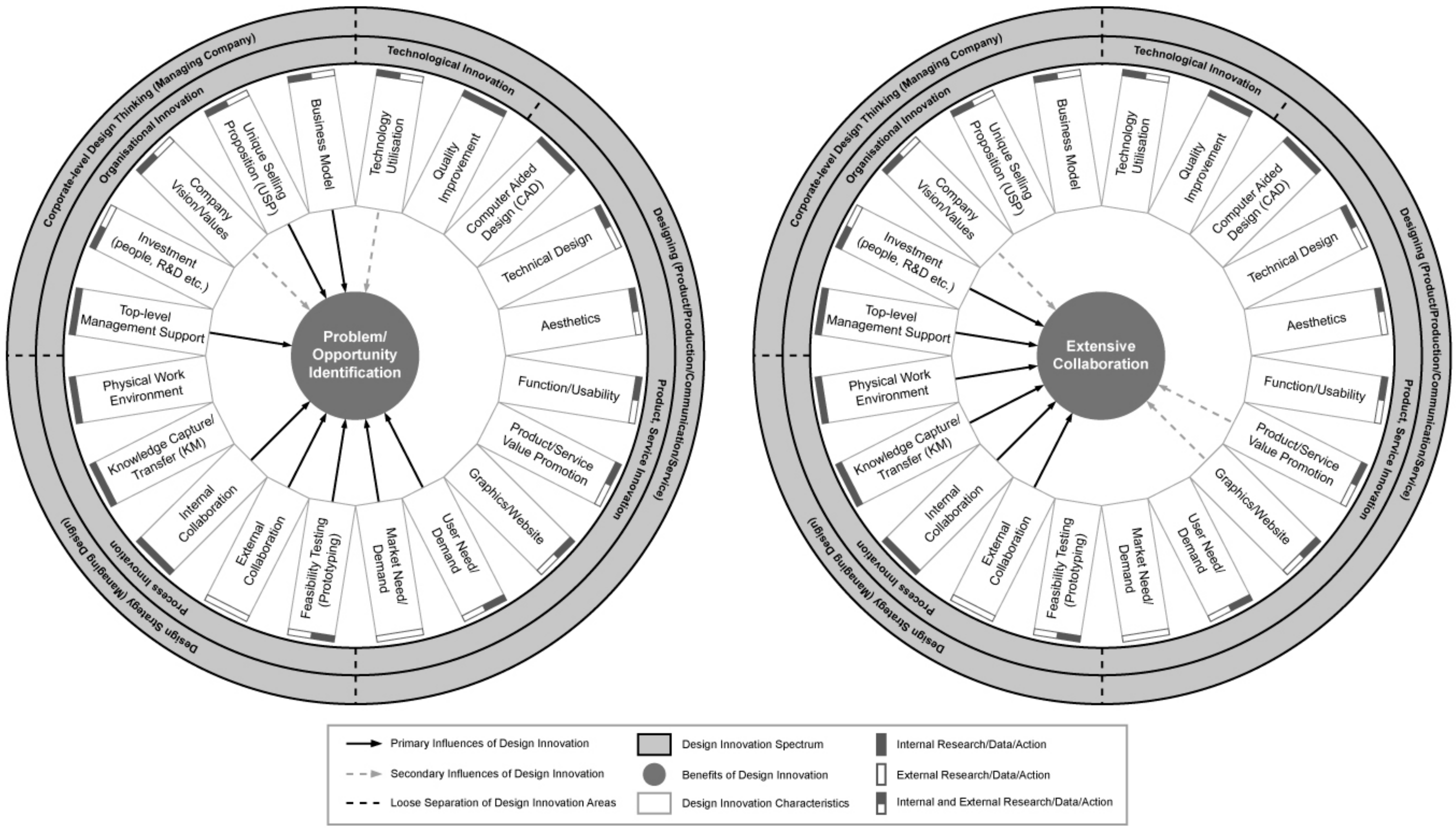
Main Goals of Design Innovation

Main Goals	Descriptions
Creative Idea Generation	Design Innovation can encourage and spark creative idea generation by using co-creation methods to enable collaboration across the whole company as well as with customers and external organisations to maximise cross-pollination. Its empathic research of the users and holistic approach in market and technology research helps to create/optimise sales channels resulting new/improved business model.
Optimising Business Environment	Design Innovation can enable effective use of resources including materials (reduced waste, maximise material utilisation), processes (modular system of product ranges), time (reduce product development and production lead time), productivity (better work environment), knowledge (transfer of tacit knowledge), investment (on where it is most needed) to optimise business performance.
Successful Commercialisation	Design Innovation can lead successful commercialisation by creating aesthetically and functionally desirable, high quality products/services that is intuitive to use and easy to manufacture. Their values and unique qualities can be effectively communicated through using graphics on the products and packages and promoted using appropriate channels for target customers.

3

Design Innovation Framework Details

Influence of Design Innovation Characteristics on Creative Idea Generation



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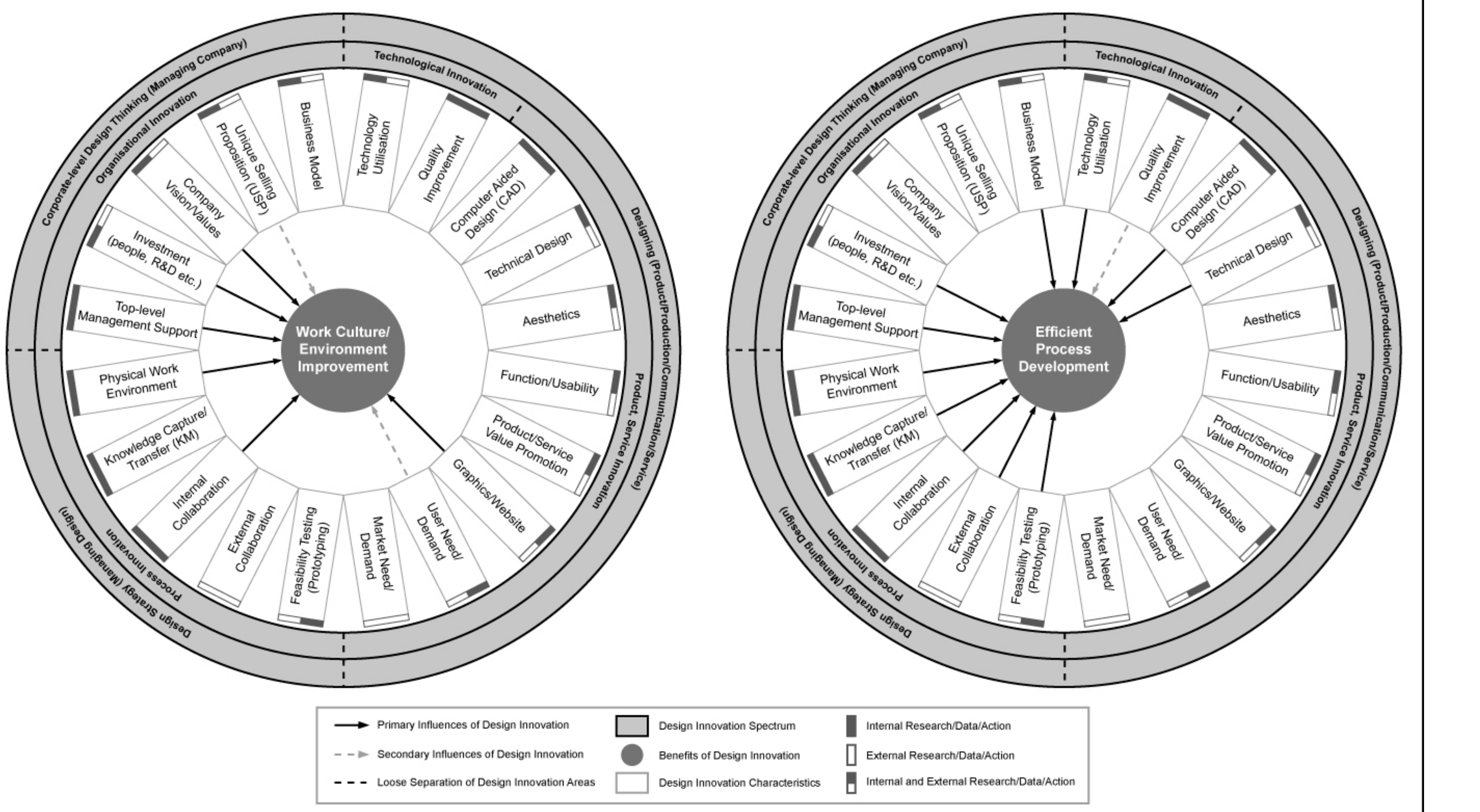
Design Innovation Framework Details

Influence of Design Innovation Characteristics on Optimising Business Environment



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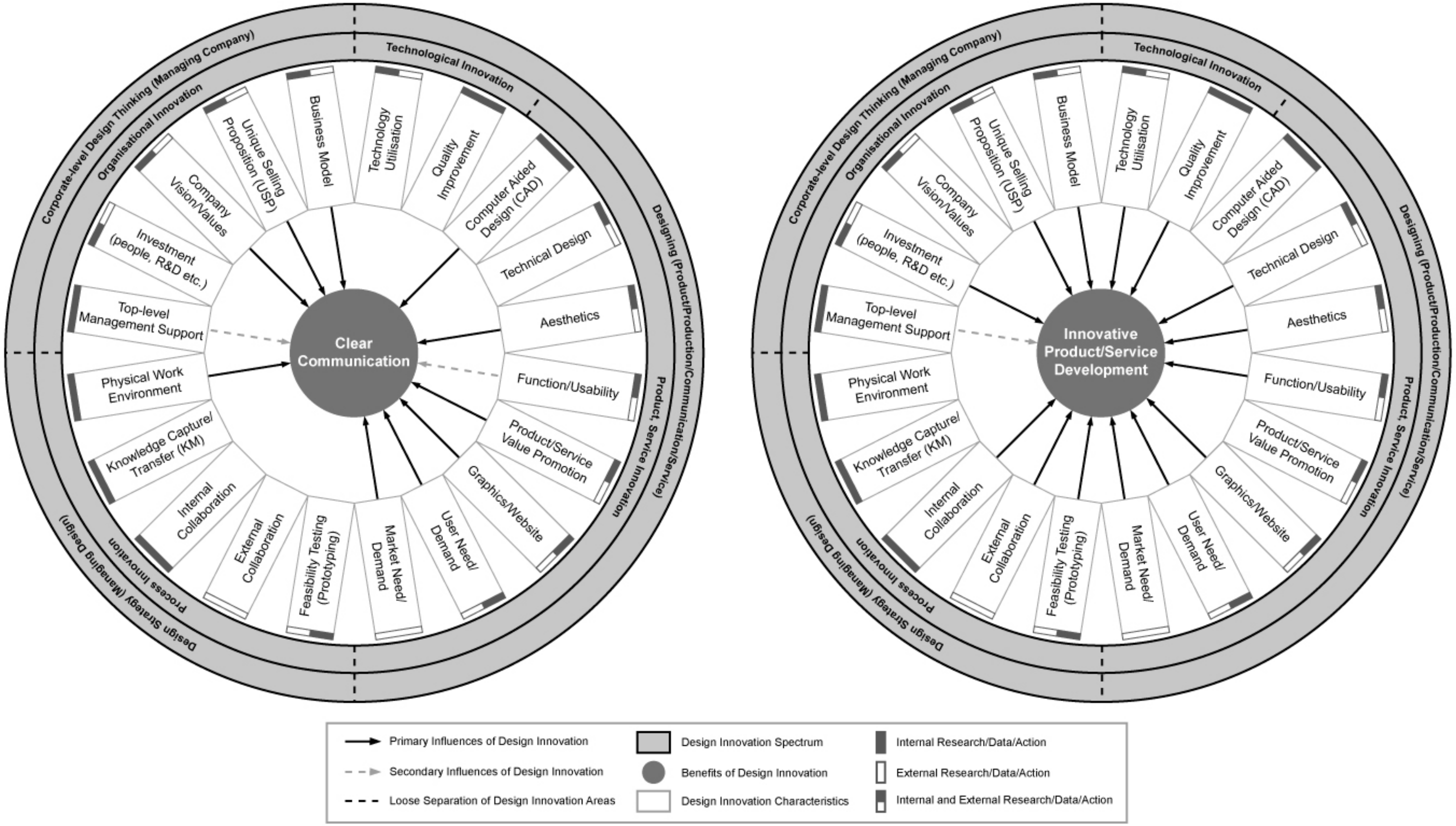
Design Innovation Framework Details

Influence of Design Innovation Characteristics on Successful Commercialisation



6

Design Innovation Characteristic Description

Characteristics	Descriptions	Details (page)
Technology Utilisation	Holistic scanning and capturing technological developments in and out of the company to be used in products/services	18
Quality Improvement	Ensuring development of high quality products both technically (help reduce failure and increase effective production) and visually(perception of high quality)	18
Computer Aided Design (CAD)	Utilisation of CAD/CAM to enable effective visualisation and virtual prototyping leading to flexible manufacturing	19
Technical Design	Optimisation of the functions of products and the components for effective production and assembly (DFM/A)	19
Aesthetics	Increasing desirability of products/services for emotional added value for the customers	20
Function/Usability	Ensuring appropriate functions and measures are embedded within products/services that are intuitive to use and easy to maintain	20
Product/Service Value Promotion	Effective communication of the value of products/services to customers and potential customers as well as to employees	21
Graphics/Website	Utilisation of creative graphics on (including UI) and around (packaging and promotional materials, websites) the product/services	21
User Need/Demand	Understanding and empathy of customers to identify their need and demand for existing and potential new products/services	22
Market Need/Demand	Holistic scanning of the current market to identify need and demand and scouting for potential new market to exploit (inc. exports)	22
Feasibility Testing (Prototyping)	Early and frequent prototyping to test feasibility for both form and function as well as for manufacturability of products/services to minimise risk of failure	23
Knowledge Capture/Transfer (KM)	Ensuring appropriate tacit knowledge (experience of the employees) are captured (often digitally) and transferred on demand	23
External Collaboration (Customer co-creation)	Collaboration with customers, suppliers and external agencies to assist product/service development (co-creation) and allow customisation both on product and process (open innovation)	24
Internal collaboration (Cross-positional, Interdepartmental)	Breaking of hierarchical barriers within a company by increasing effective internal communication, and encouraging collaboration between departments to share insights to enable cross-pollination	24
Top-level Management Support	Appreciation of the importance of design innovation by the top-level management with design innovation champions within a company to encourage company-wide design adaptation	25
Physical Work Environment	Create work environment (physical) that is exciting to work in and one that encourages collaboration	25
Investment (HR, R&D etc)	Holistic analysis of the areas that require more resources in order to enable innovation culture and invest or help secure external investments	26
Company Vision/Values	Creation of shared vision and values of a company and enable effective communication to the employees to encourage employee ownership and dedication	26
Unique Selling Proposition (USP)	Identification or creation of the USP of products/services and the company itself to differentiate in the competitive market	27
Business Model	Evaluation of current sales channels and overall business practices to identify improvements or to create more effective channels to maximise profit and customer reach	27

Design Innovation Framework Implementation Process

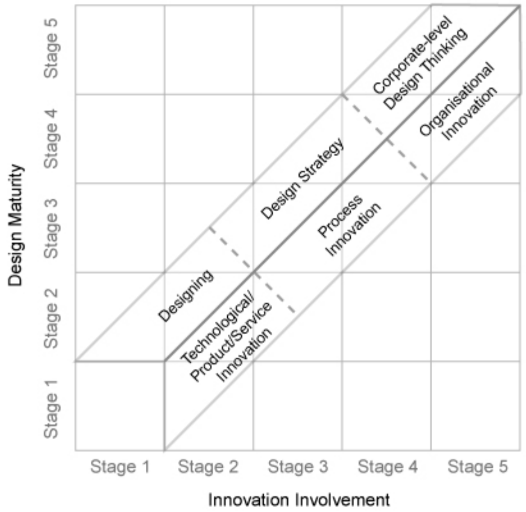
Introduction

Every manufacturing company has different problems with varying priorities and circumstances with different levels of design innovation adaptation or maturity. Therefore it is difficult to generalise the implementation guideline for the Design Innovation Framework that fits in all situation. Hence, this research uses scenario method to provide three common situations, created from studying 40 innovative manufacturing companies in the UK, to illustrate how the Design Innovation Framework can be implemented.

The implementation process requires the companies to understand the business situation where problems and/or opportunities are realised with willingness to use the framework to help improve their innovativeness. Also, whilst running a business environment scanning, they would have conducted a design maturity and innovation involvement assessment to place their company within Design Innovation Matrix.

Design Innovation Matrix

(Design Maturity, Innovation Involvement and Design Innovation Spectrum)



	Design Maturity	Innovation Involvement
Stage 1	No Design- Design plays no role in product/service development	Little or no systematic innovative involvement
Stage 2	Design as Styling- Design is only relevant in terms of style	Some systematic innovative involvement in parts of organisation
Stage 3	Design as Process- Design is integral to the development process	Aligning strategic goals with systematic innovation
Stage 4	Design as Strategy- Design is a key strategic means of encouraging innovation	Internally initiated, open-ended learning innovative involvement
Stage 5	Design as Culture- Design thinking practiced in all levels of business	Innovative involvement as a dominant culture

Design Innovation Framework Implementation Process

Further development in Design Innovation framework for total design innovation

Acknowledgement of Problem/Opportunity	Business Environment Scanning	Review Mission and Vision Statements	Benchmarking	Identify Design Innovation Characteristics to Develop	Create Programme and Allocate Budget	Evaluate Outcome
Business problems such as decreasing sales and increasing competition, stale business, or opportunities through new technology development are acknowledged.	Understand the position of the company and its products/services in the current market. Prioritise the core area to develop to maximise strength and reduce weakness of the company.	Identify, and revise if necessary, the reason for the company's existence and values that it manifests both internally and externally.	Assess the performance level of best practice in the sector (or the company's own desired level) using the six benefits of Design Innovation.	From the Design Innovation Framework, identify the priority characteristics and its elements develop.	Create programmes to deliver the outcome including timing responsibilities and cost to achieve the target.	Measure actual outcome of the programmes against objectives, reviewing and amending as necessary.

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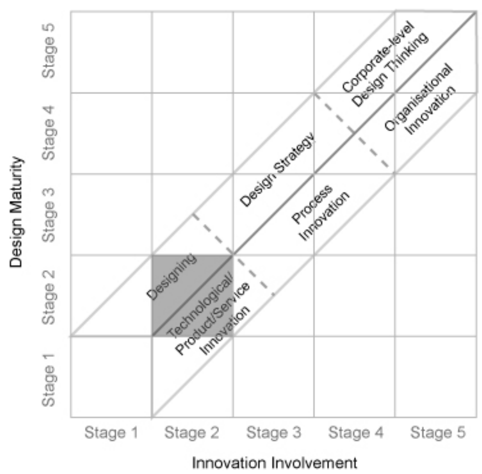
Design Innovation Framework Implementation

Scenario 1: ‘Company A’ with decreasing market share and customers

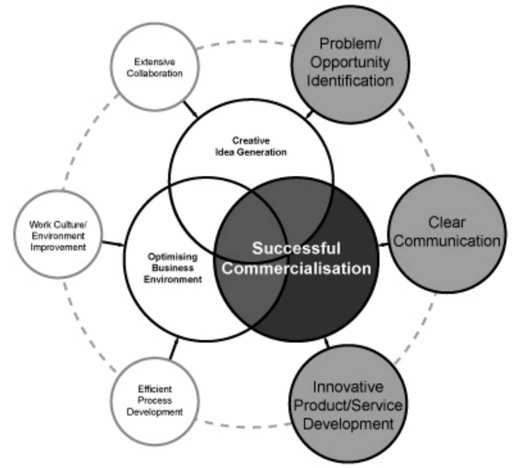
Background

Company A is a manufacturing company that supplies temperature measurement device for oil & gas industry to ensure pipelines are at constant temperature. The company was founded by group of researchers with engineering background when they developed a new technology that can be used in extreme environment with great accuracy which can be produced at relatively low cost. The first product was launched 15 years ago. The product has been improving over the years for better accuracy, however, the competition has increased, especially from overseas that can provide similar function with even lower price. With declining sales of the product, the company is looking to survive in the market.

Design Innovation Matrix for Company A



Design Innovation Framework with strategic priority in Succesful commercialisation



Design Innovation Framework Implementation Process (Part 1)

Acknowledgement of Problem/Opportunity	Business Environment Scanning	Mission and Vision Statements	Benchmarking
The founders and top-level managers are aware of falling market share and sales. However, recent introduction of less sophisticated but cheaper product made by companies in Italy and Brazil have become such a threat that they are starting to lose even the regular clients who are stringently cutting costs due to global oil price decrease. In an annual strategic meeting, they have all agreed they need to increase innovativeness to compete in the market, and hence decided to hire a design innovation consultancy as recommended by the Business Growth Service (former MAS). The consultancy uses Design Innovation Framework to assess, advice and deliver better innovation for the company.	Main product of the Company A is in the late stage of its lifecycle where adoption and sales are both declining. The consultants ran series of workshop sessions with top-level managers and key employees to critically evaluate the company situation and position using both traditional tools familiar to the stakeholders such as SWOT analysis and Boston Matrix, and some design-led tools such as Lovemark and Design Innovation Matrix. The priority was initially set on ‘successful commercialisation’ within the Design Innovation Framework as it was the most urgent area to survive in the market. The core competence of the company was identified as its unique patented technology that accurately measures temperatures in higher pressure than any other competitors.	There was no mission and vision statements for the company. However, the top-level managers realised the importance of the statements to address company values to both its employees and their customers. After the workshop, with consultants, top-level managers and participating employees in different departments, they have created mission and vision statements that represent the company’s core competence and values.	The leading company in similar sector as the Company A was identified to benchmark its performance. The performance of six areas of design innovation benefits are identified and compared with self assessment of the Company A. Problem/Opportunity identification, clear communication, Innovative product/service development, efficient process developments showed biggest difference in performance. Therefore these areas were chosen to be further developed and the company’s strategic priority was confirmed to be the ‘successful commercialisation’ to increase product/service and process innovativeness.

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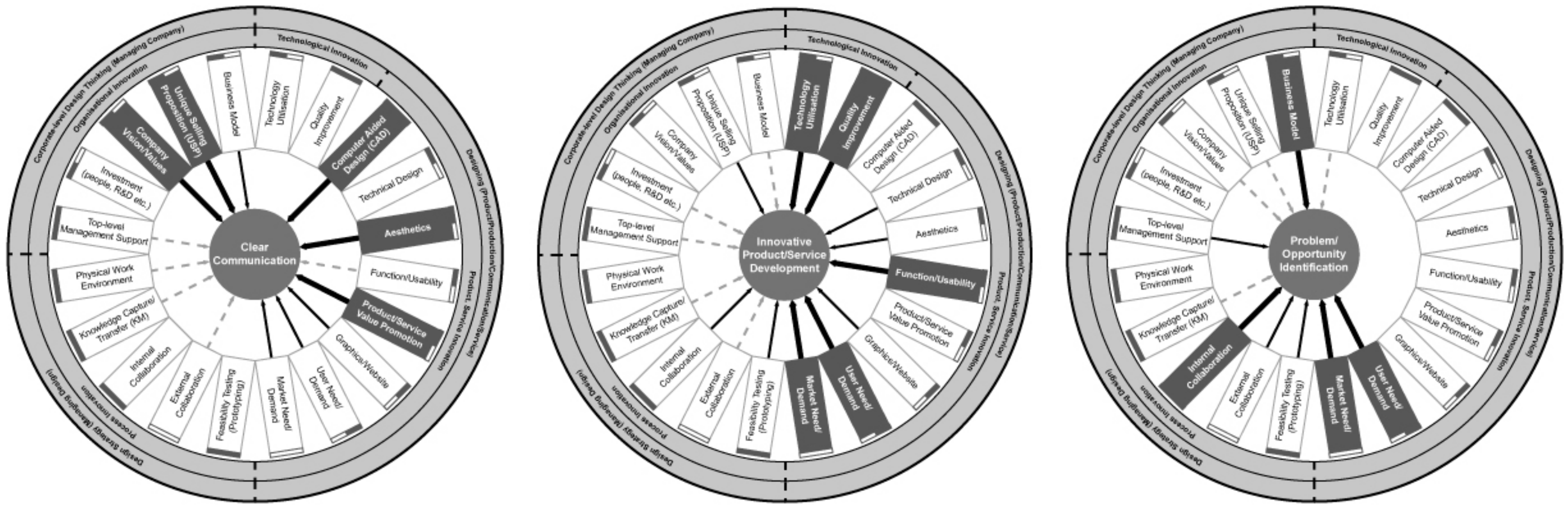
Design Innovation Framework Implementation

Scenario 1: 'Company A' with decreasing market share and customers

Detailed charateristics (in grey) to fulfill strategic priorities and to encourage successful commercialisation for the Comany A



Design Innovation Framework Implementation Process (Part 2)

Identify Design Innovation Characteristics and its Elements to Develop	Create Programme and Allocate Budget	Evaluate Outcome
For clear communication, design innovation characteristics including computer aided design (digitising ideas, better visualisation of concepts), aesthetics (communicate quality, convey brand message), product/service value promotion (visual communication, identify effective promotion methods), company vision/values (communicate company vision) and unique selling proposition (emphasis USP in product/service, communicate USP) were identified as priorities. For innovative product/service development, technology utilisation (identify appropriate technology gap), quality improvement (simple component design, design for effective assembly), aesthetics (leading trend), user need/demand (forecast future demand, identify opportunity for new users) and market need/demand (prioritise improvements in the market) were characteristics to prioritise. Finally, to enable better problem/opportunity identification, user need/demand (identify customer journey, utilisation of design research methods), market need/demand (understand current market, scout for new market, identify competition), internal collaboration (encourage idea sharing, communication between stakeholders) and business model (identify new sales channel, utilisation of design-led tools to create business model) were identified to be improved.	The design innovation consultancy have developed series of programmes focusing on using design to develop appropriate areas identified as priority. Not all programmes were executed to keep the development within a budget. The final outcome is series of products that complements the existing product. The emphasis on delivering brand image of quality and technological advancement were advocated through aesthetics and communications for the new products. The products are positioned in high-end of the market with expansion to aerospace and defence with increased exports.	Programmes developed using the design innovation framework have been mostly successful. The strategic targets to survive in the market with increasing competition have been satisfied with increased competitiveness by using design innovation elements. Furthermore, new overseas market has provided with the company much needed cash flow to invest in other areas of design innovation benefit (creative idea generation) to increase the company's innovativeness further towards the Total Design Innovation.

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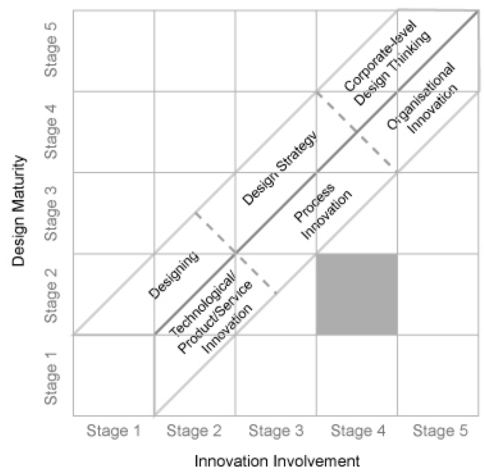
Design Innovation Framework Implementation

Scenario 2: Established ‘Company B’ that wants to expand its business

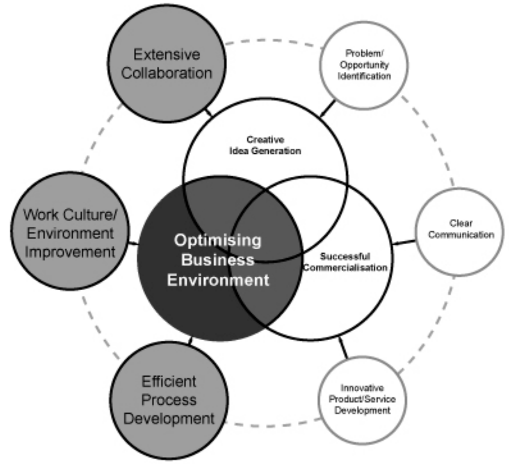
Background

The manufacturing company B has stable list of clients with solid demand for its products and services. The company has been established 40 years ago and it produces electrical switches for both domestic and commercial use (B2C and B2C) with 80 percent of its sales within the EU. The company is known for its product reliability with continuing improvements to satisfy the demand of the current users. It is also capable of providing bespoke products in small batches and subsequent services to its clients by using flexible manufacturing method. However, the directors of the company want to anticipate fast changing market environment by increasing innovativeness of the company.

Design Innovation Matrix for Company B



Design Innovation Framework with strategic priority in Successful commercialisation



Design Innovation Framework Implementation Process (Part 1)

Acknowledgement of Problem/Opportunity

The company is stable with its cash flow and revenue. However, there is agreement among top-level managers that business has become stale both in the product offerings and in work culture. Therefore they have decided to improve their innovativeness to ensure they can expand their business as well as anticipate for the future competition. There is a dedicated innovation team which offer the customer with new or improved products every year. However, the directors have agreed to utilise the team to develop process and organisational innovation to increase profit margin and competitiveness of the company. The innovation team have decided to use the Design Innovation Framework to diagnose and improve innovation for the company.

Business Environment Scanning

The innovation team has conducted series of interviews with employees in various department to understand the work culture and to identify the areas that could be improved. They have found that the production process of the company B has not been changed for over 20 years. There is large proportion of employees on the shop-floor who have been with the company for over 10 years, however, their involvement is minimal in the new product development. There is a design team that consists of engineering designers and product designer, however, their involvement in innovation is also scarce. The findings was presented in a board room meeting and the directors have decided to prioritise ‘optimising business environment’ as a priority.

Mission and Vision Statements

The mission of the company is to provide reliable light switches that can be used everywhere from home to space stations. However, the mission and vision of the company was not communicated adequately both internally and externally. After a workshop with key employees, directors and external consultants, additional competence of the company. Therefore, the mission and vision has been altered to also emphasise this new capabilities.

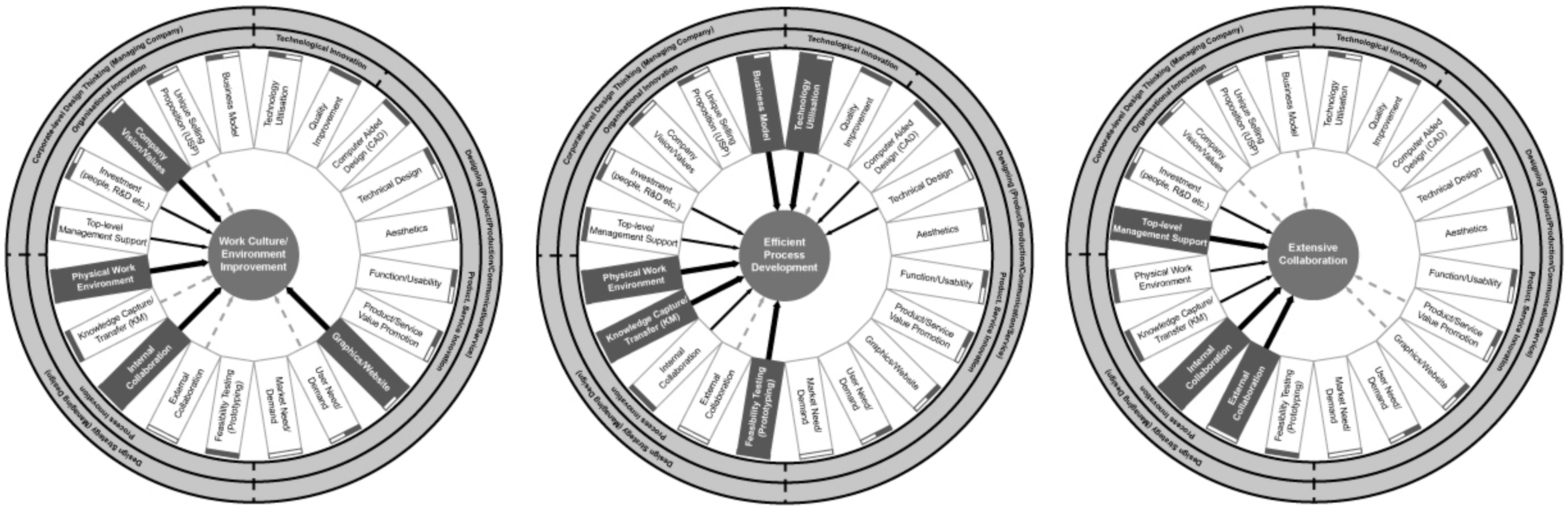
Benchmarking

The innovation team also ran a workshop that invited academics in the same sector and consultants who have worked within the similar sector to understand the market situation. They have benchmarked three companies, one is most well known global and innovative company, another is the a company in similar sector, and finally a company that is a direct competitor with the company A. Through the session, the company decided to prioritise ‘efficient process development’, ‘work culture/environment improvement’ and ‘extensive collaboration’ led by the innovation team in the first phase of the innovation development.

Design Innovation Framework Implementation

Scenario 2: Established 'Company B' that wants to expand its business

Detailed charateristics (in grey) to fulfill strategic priorities and to encourage successful commercialisation for the Comany B



Design Innovation Framework Implementation Process (Part 2)

Identify Design Innovation Characteristics and its Elements to Develop	Create Programme and Allocate Budget	Evaluate Outcome
To enable extensive collaboration, internal collaboration (extracting implicit knowledge, communication between stakeholders, synthesis of ideas, place for collaboration), external collaboration (involve users/clients in NPD, identify areas needed for external collaboration, interpret and mediate information, develop programme of collaboration), top-level management support (prioritise innovation) were identified as a priorities to be improved. For work culture/environment improvement, design innovation characteristics including company vision/values (create customer focused vision, identify key values, encourage employee participation), physical work environment (optimising production/assembly flow, flexible working space), internal collaboration (encourage idea sharing, communication between shareholders) and graphics/website (consistent internal branding, clear communication) were identified as priorities. Finally, for efficient process development, technology utilisation (identifying appropriate technology, identification of technology gap), feasibility testing (identify user preferences), knowledge capture/transfer (visualise knowledge pool, identify the expertise required in NPD, improve articulation of experiences), physical work environment (optimise production/assembly flow, flexible working space), and business model (identify new sales channel, holistic overview of business model, utilisation of design-led tools to create business model, identify problem/opportunity in business operation) were characteristics to prioritise.	Based on the priority design innovation characteristics, briefs for design innovation and engineering design agencies were created. Objectives of the collaboration between the agencies and the innovation team are: (i) review and create business model to increase profit, (ii) develop internal branding to enable better communication within the company (iii) increase employee engagement in NPD and idea sharing by including collaboration space between shop floor and offices, and (iv) optimise production process by utilising the latest technology to reduce wasted space and resources.	A design innovation consultancy was hired and together with the innovation team, they have conducted projects to fulfil the objectives (i) and (ii). Internal branding has changed the work culture significantly. The employees are much more satisfied with the work and they have started to share ideas more frequently. Implicit knowledge of more experienced staffs have are being cross-pollinated in different departments. The company has started second phase of optimising business (objectives (iii) and (iv) which is initiated by collaboration across employees, led by the innovation team.

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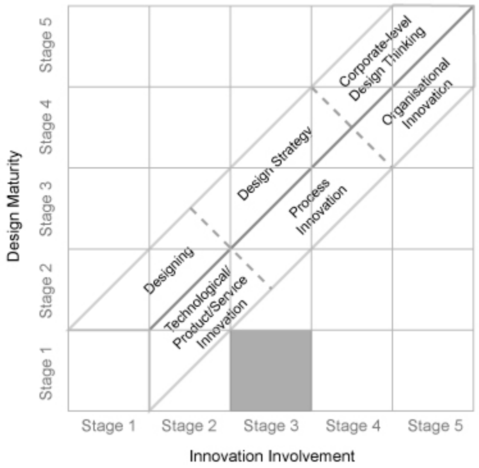
Design Innovation Framework Implementation

Scenario 3: Technology Entrepreneurial Start-up 'Company C'

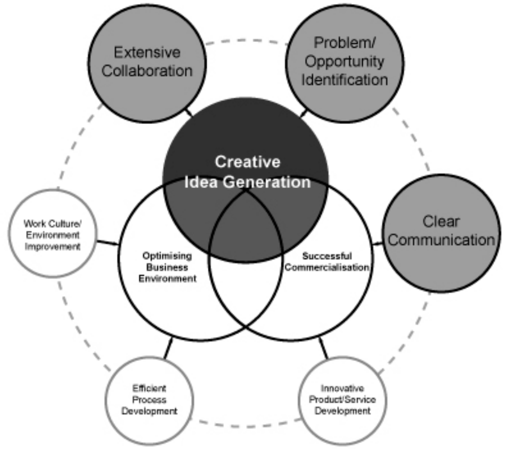
Background

Company C is a start-up manufacturer that produces products using technology developed from a university research lab. The core technology is the ability to manipulate specially formulated aluminium allow power to create 3D object with high accuracy by using self-built 3D printer. It produces bespoke parts for formula one cars and for military application. The company has been given government grant to set up, however, it requires further investment to continue refining the process to be more widely available. In addition, the founders want to build the company to adopt the theory of total design innovation in order to build an innovative business that can lead the market.

Design Innovation Matrix for Company C



Design Innovation Framework with strategic priority in Successful commercialisation



Design Innovation Framework Implementation Process (Part 1)

Acknowledgement of Problem/Opportunity	Business Environment Scanning	Mission and Vision Statements	Benchmarking
The founders of the company are looking to build a company that excels in innovation in order to find new opportunities with the technology that they have already in-house. As a start-up company, the company operation is not systematic but at the same time, very flexible in adopting new approaches. The company is now working with a university that runs design innovation boost programme for technology start-ups. The programme uses Design Innovation Framework to support manufacturing companies to practice total design innovation that addresses comprehensive design innovation areas to enhance competitiveness of the company.	A design innovation consultant was linked with the company by the university support programme. The consultant ran a workshop with founders and employees of the Company C to identify the business environment which the company is in using brainstorming and PESTEL tool. Together they have identified core competence of the company, not only in technological sense but also in how they create a product as demanded by their clients. Furthermore, they have identified their lack of systematic process of idea generation that leads to a new product because the company only relied on fulfilling client requests to produce bespoke products. Therefore the company have decided to initiate the total innovation journey with 'creative idea generation'.	The focus of the company has been on technology advancement. However, the workshop has provided with new ideas and possibilities. Therefore the founders identified new vision for the company which is to focus more on cultivating and utilising creativity to become more innovative in the areas of product, service, process and the organisation as a whole. The perception of design has changed as well where they are now thinking of hiring a design director to lead all design innovation operations within the company.	Second workshop was held with the consultants and other professionals in the field similar to the company C. The company founders have identified few companies that they would like to benchmark prior to the workshop. Some were multinational company in different sector and some were some organisations in same sector. Initial discussion was on identifying the level of performance in the six essential benefits of design innovation. Further desk research supported in identifying priority areas for the company which were 'extensive collaboration', 'problem/opportunity identification', and 'clear communication'.

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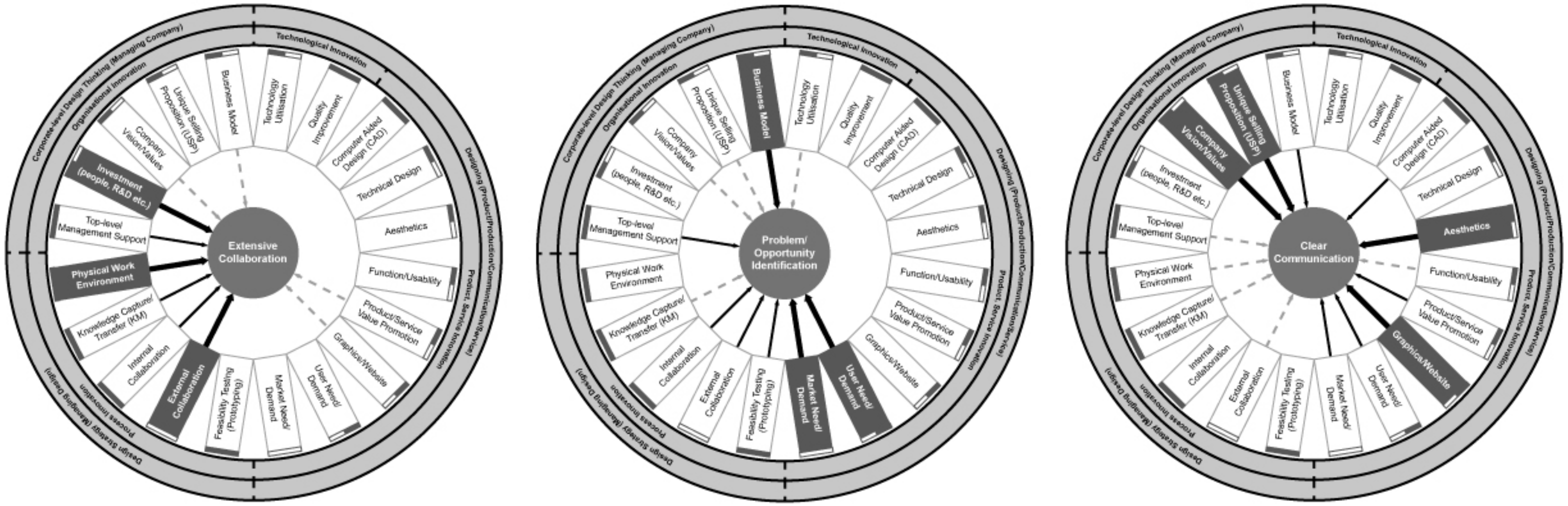
Design Innovation Framework Implementation

Scenario 3: Technology Entrepreneurial Start-up 'Company C'

Detailed charateristics (in grey) to fulfill strategic priorities and to encourage successful commercialisation for the Comany C



Design Innovation Framework Implementation Process (Part 2)

Identify Design Innovation Characteristics and its Elements to Develop	Create Programme and Allocate Budget	Evaluate Outcome
To enable extensive collaboration, investment (investment in design expertise), physical work environment (flexible working space, space for collaboration), external collaboration (identify areas needed for external collaboration, develop programme of collaboration) were identified as a priorities to be improved. For problem/opportunity identification, design innovation characteristics including business model (identify new sales channel, utilisation of design-led tools to create business model), user need/demand (forecast future need/demand, identify opportunity for new users), and market need/demand (scout for new market opportunity, prioritise improvements for the market) were identified as priorities. Finally, for clear communication, aesthetics (communicate quality, convey brand message), graphic/website (consistent branding, attractive promotional material, engaging website), company vision/value(communicate company vision),and unique selling proposition (communicate USP, focus resources to develop USP) were identified as characteristics to prioritise.	The company, with support from the consultant, created a strategic plan to achieve to develop the priority design innovation characteristics. First they have emphasised the USP and branding of the company and created business model which was received well by new investors. With the investment, the company hired new creative director to create design-led programmes in order to understand potential new the users and markets in order to find opportunities. Furthermore, the company has created set of programmes to enhance creativity in NPD and new service offerings to utilise its technology in a new market.	The programmes developed through design innovation framework and the collaboration with the university has made the company to be more competent in identifying opportunities and deliver products and services which potential users would value. The immediate fanatical achievement through new investment has help the company to grow its design innovation capabilities and expand into new markets by understanding the new users. The company now seeks to improve its innovativeness further by developing other design innovation characteristics, working towards becoming a total design innovation company.

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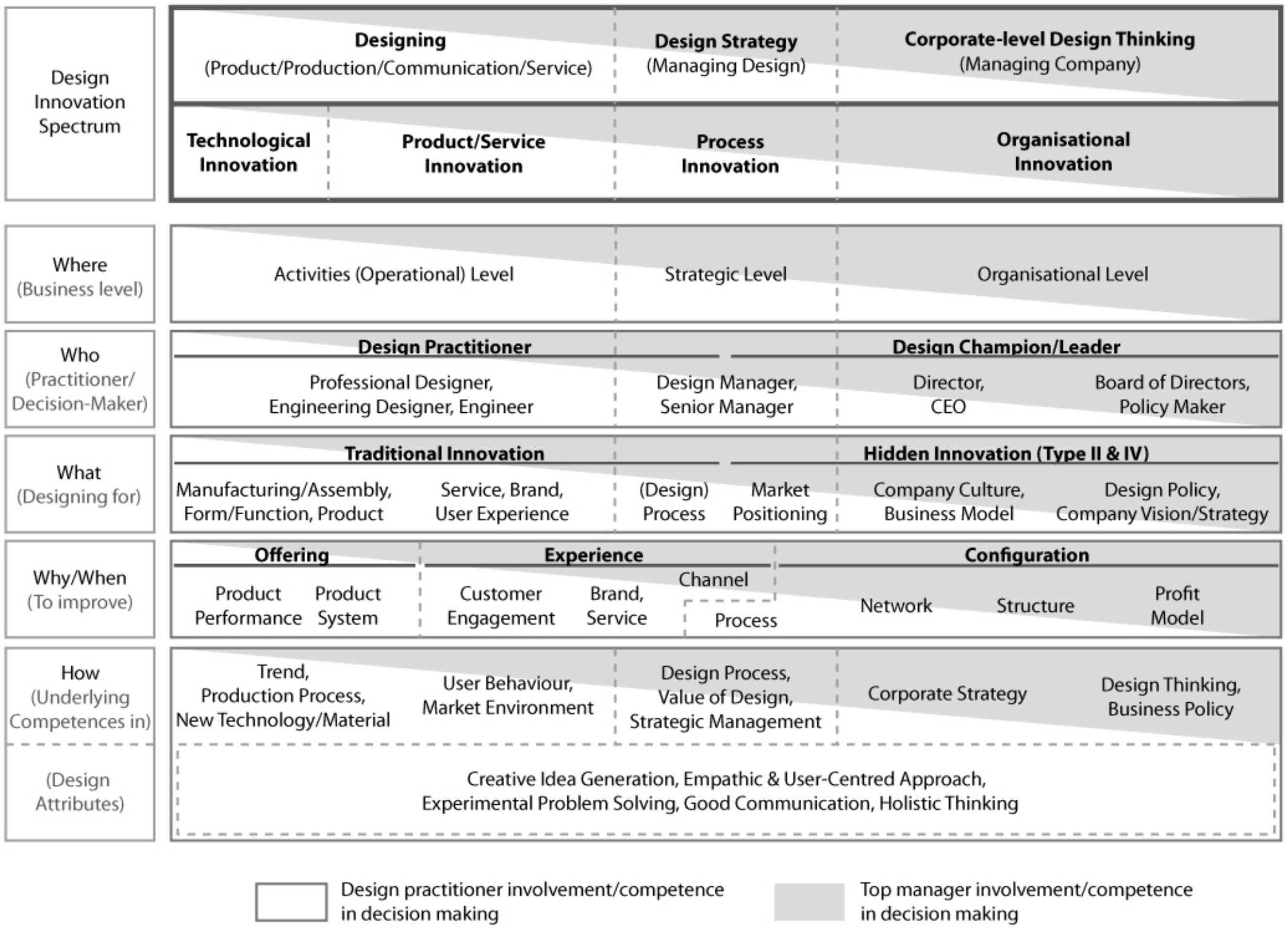
Design Innovation Framework
Further Details

Design Innovation Spectrum



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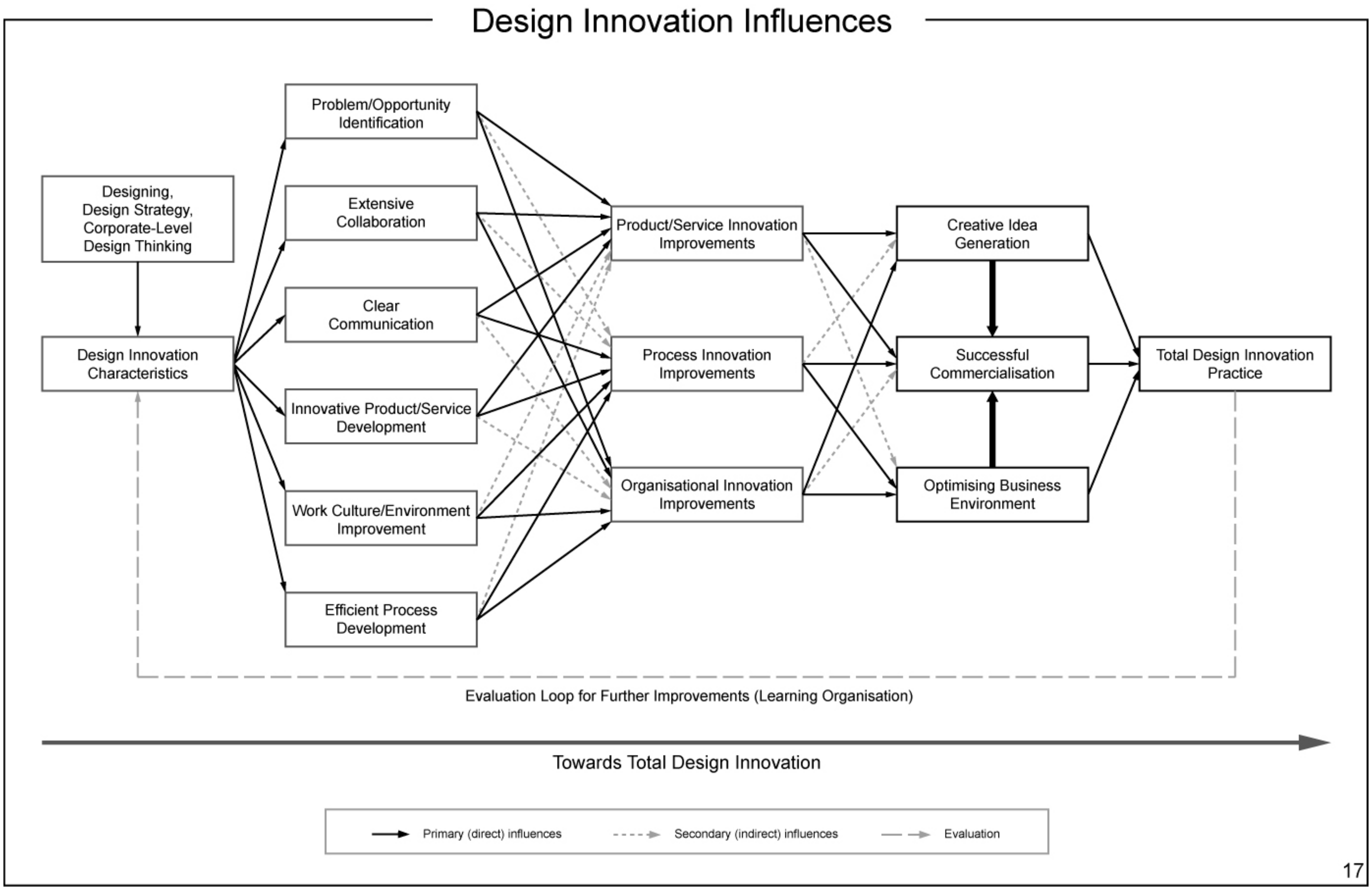
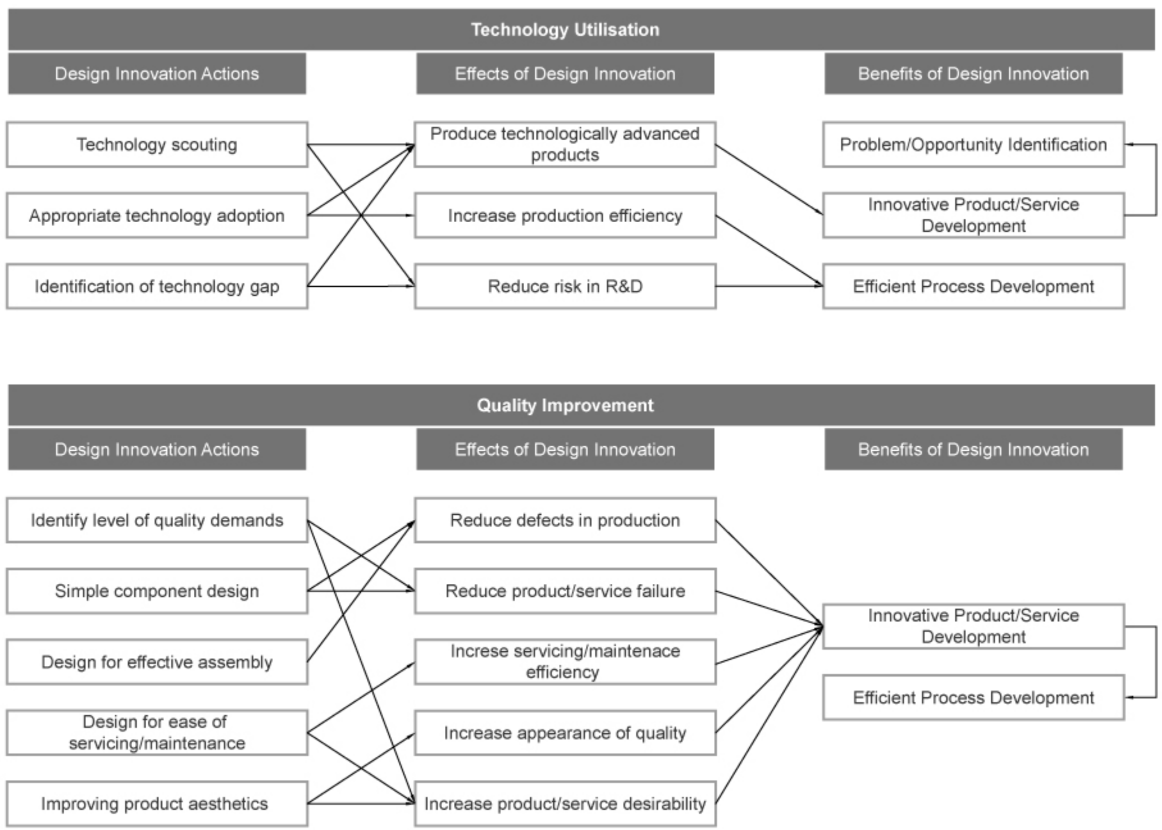


Design Innovation Influences
Designing, Design Strategy, Corporate-Level Design Thinking
Design Innovation Characteristics
Problem/Opportunity Identification
Extensive Collaboration
Clear Communication
Innovative Product/Service Development
Work Culture/Environment Improvement
Efficient Process Development
Product/Service Innovation Improvements
Process Innovation Improvements
Organisational Innovation Improvements
Creative Idea Generation
Successful Commercialisation
Optimising Business Environment
Total Design Innovation Practice
Evaluation Loop for Further Improvements (Learning Organisation)
Towards Total Design Innovation
Primary (direct) influences
Secondary (indirect) influences
Evaluation
17

Design Innovation Characteristics: Actions, Effects and Benefits



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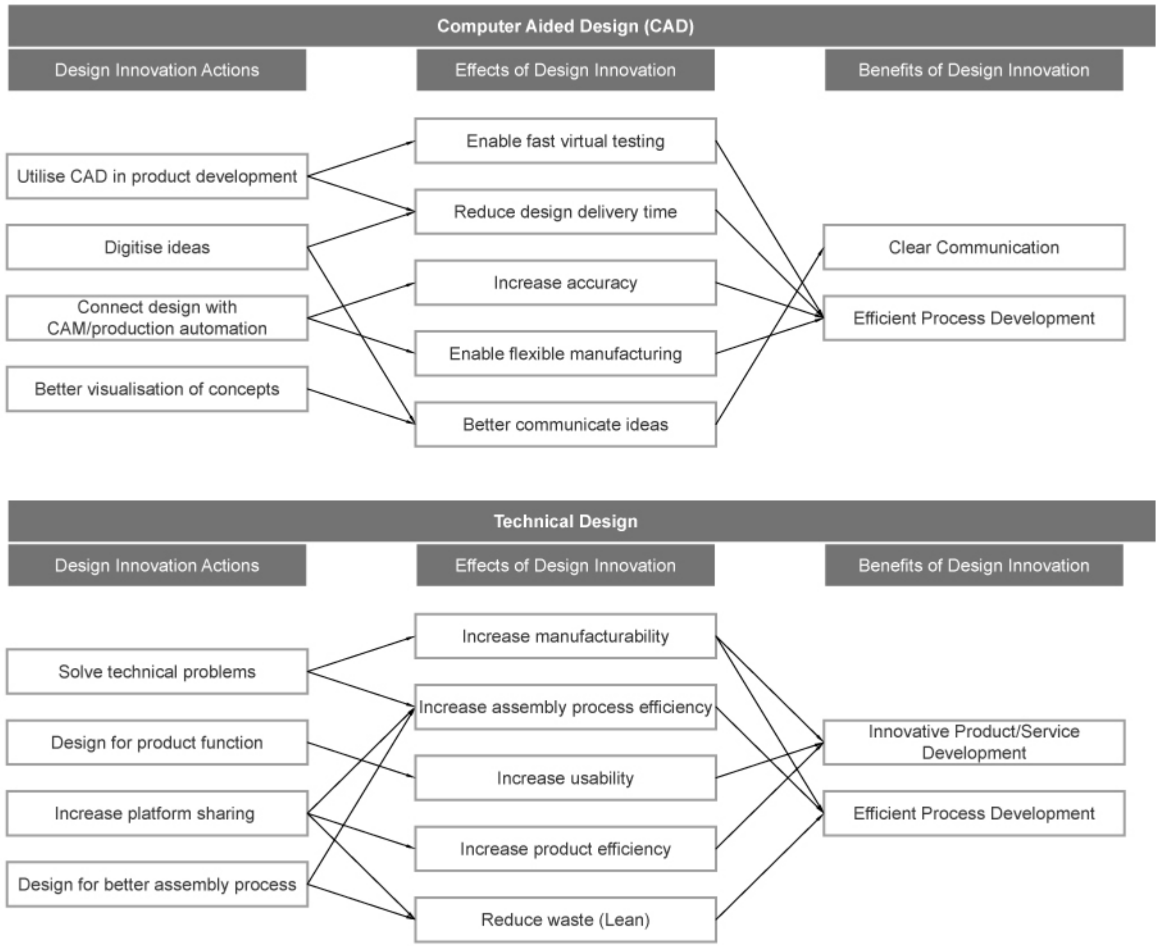
Design Innovation Characteristics: Actions, Effects and Benefits



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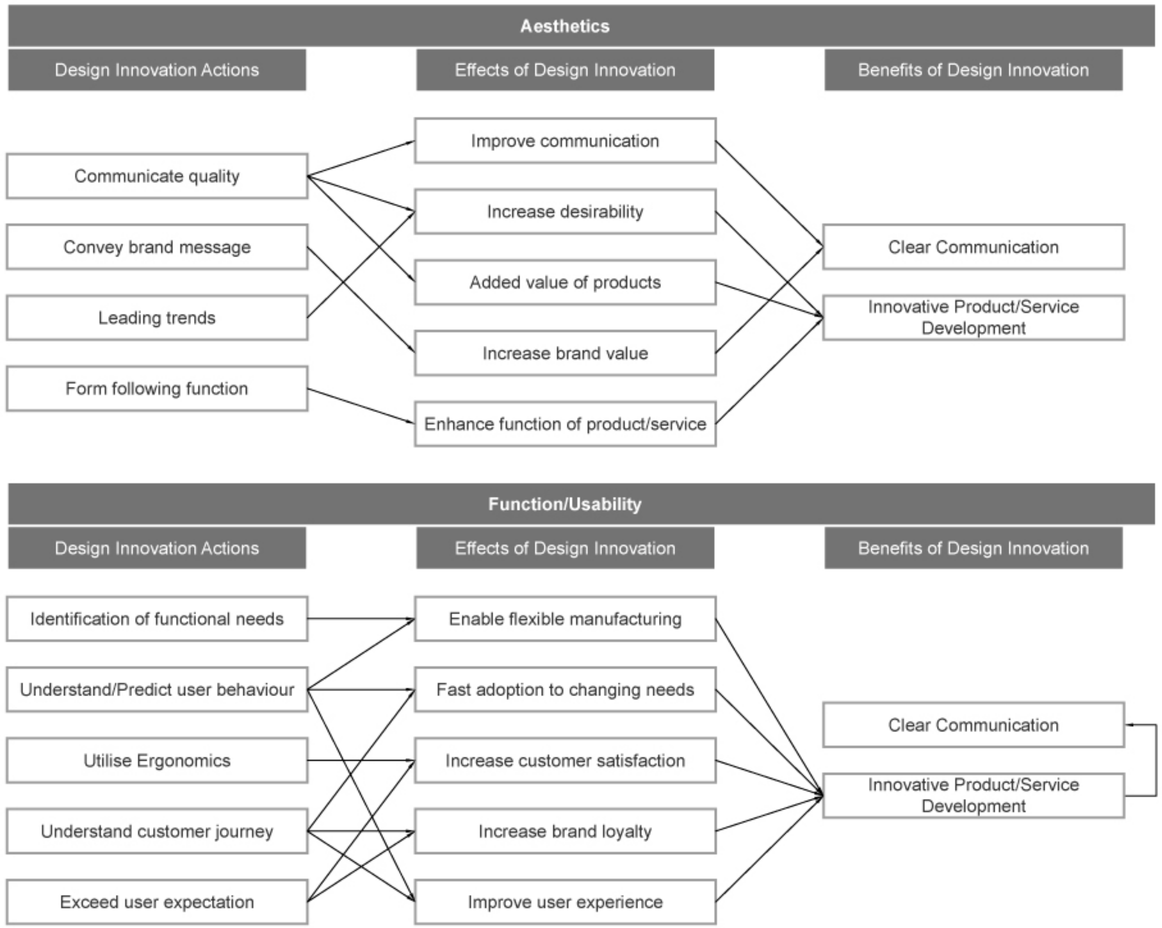
Design Innovation Characteristics: Actions, Effects and Benefits



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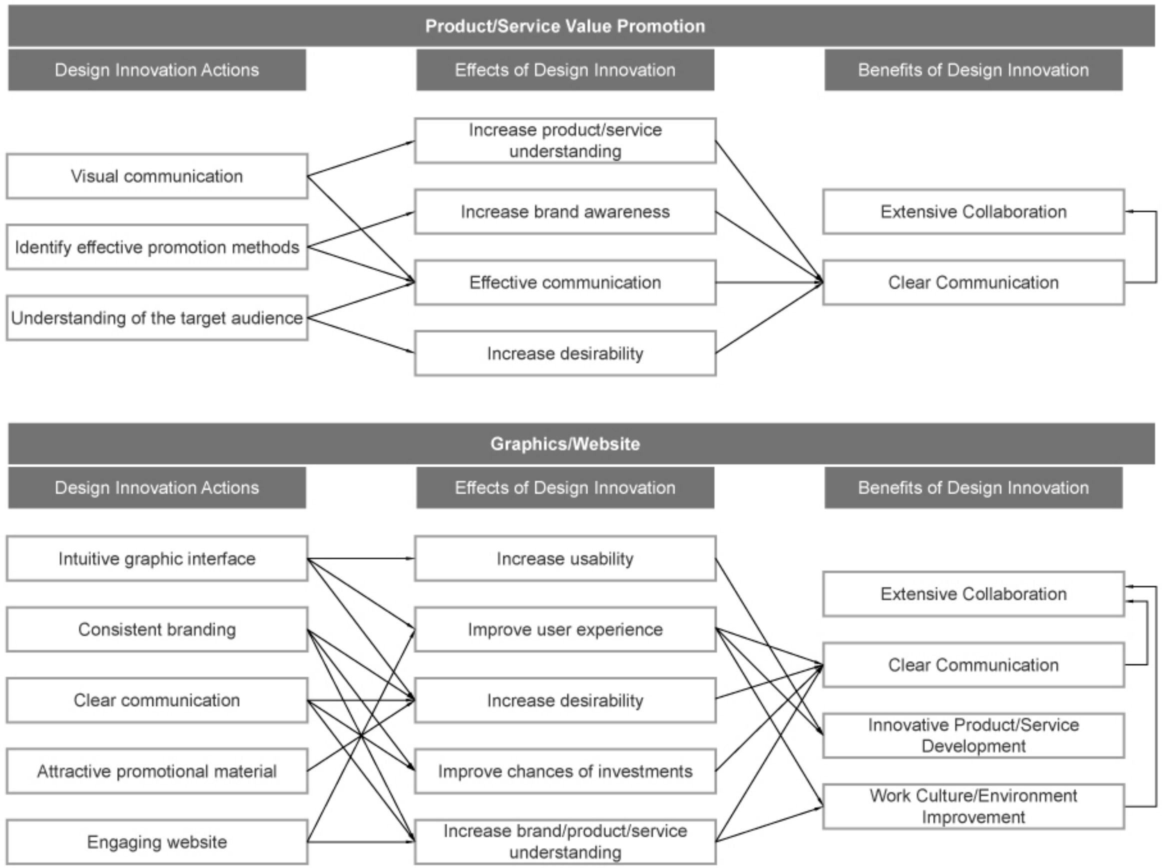
Design Innovation Characteristics: Actions, Effects and Benefits



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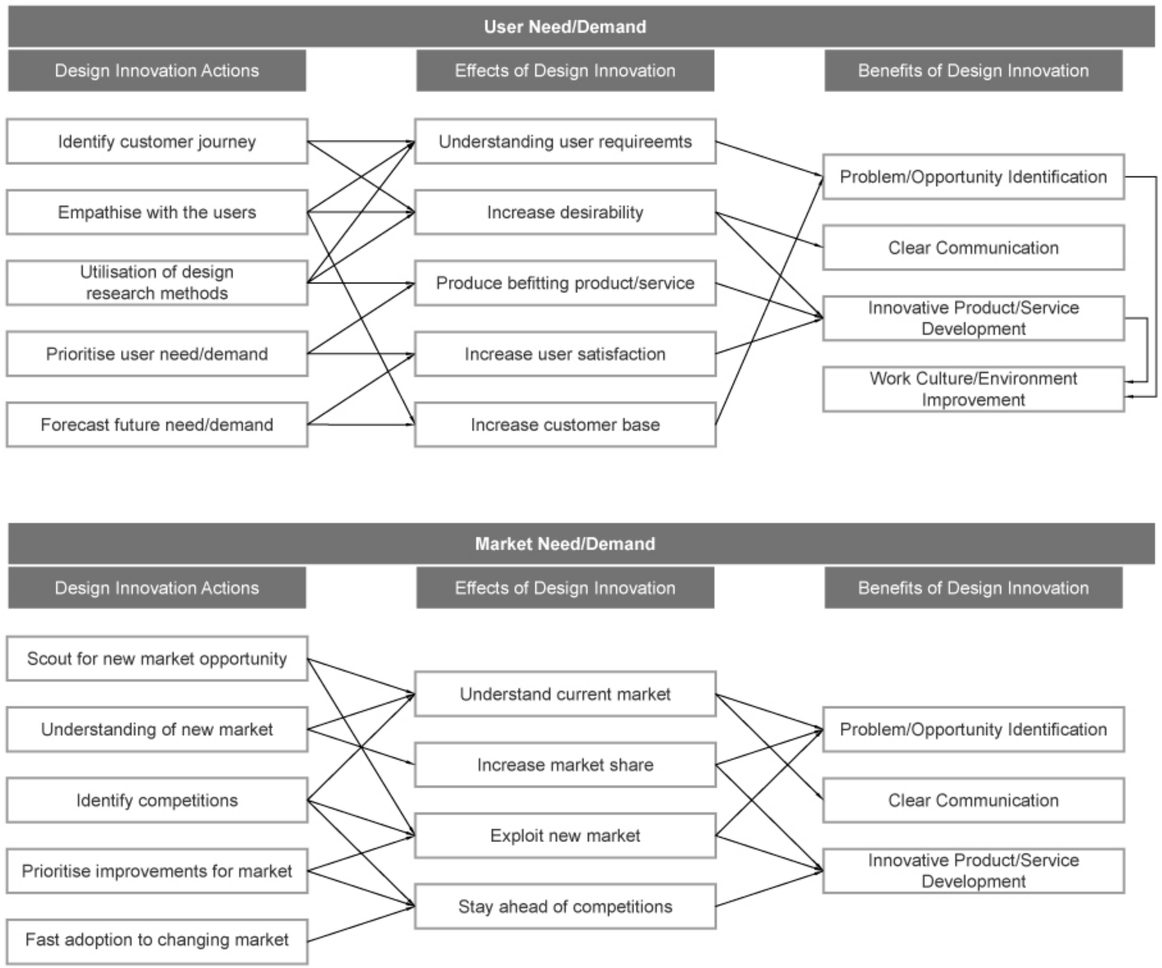
Design Innovation Characteristics: Actions, Effects and Benefits



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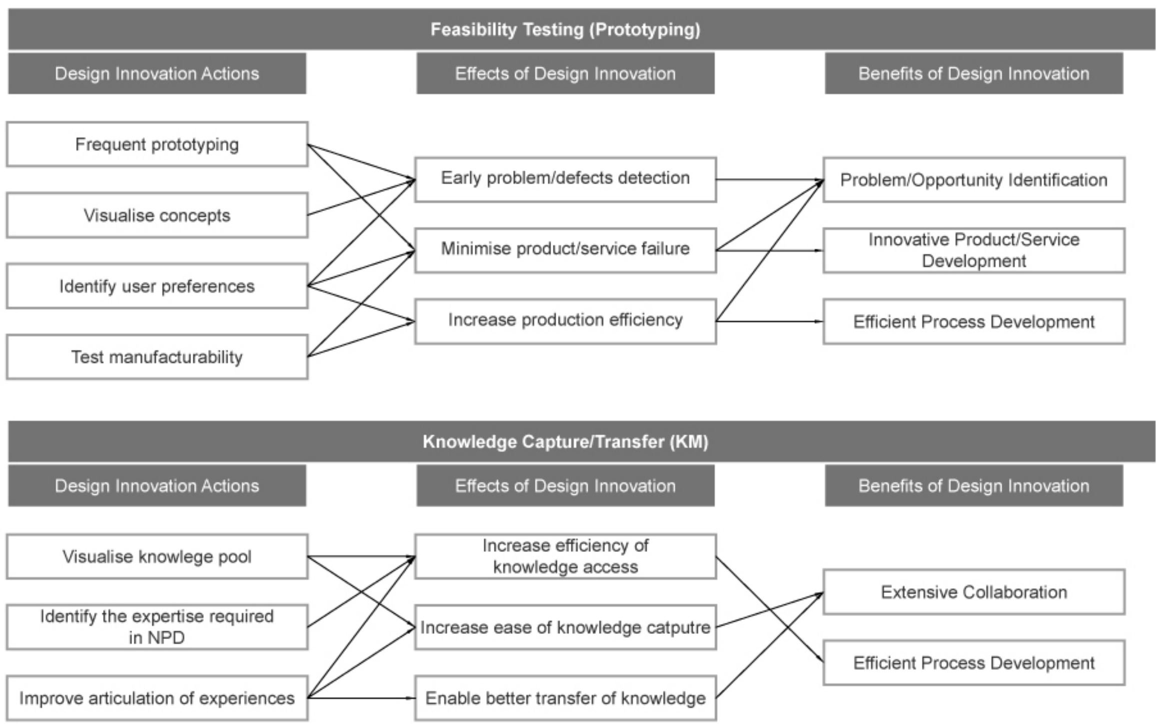
Design Innovation Characteristics: Actions, Effects and Benefits



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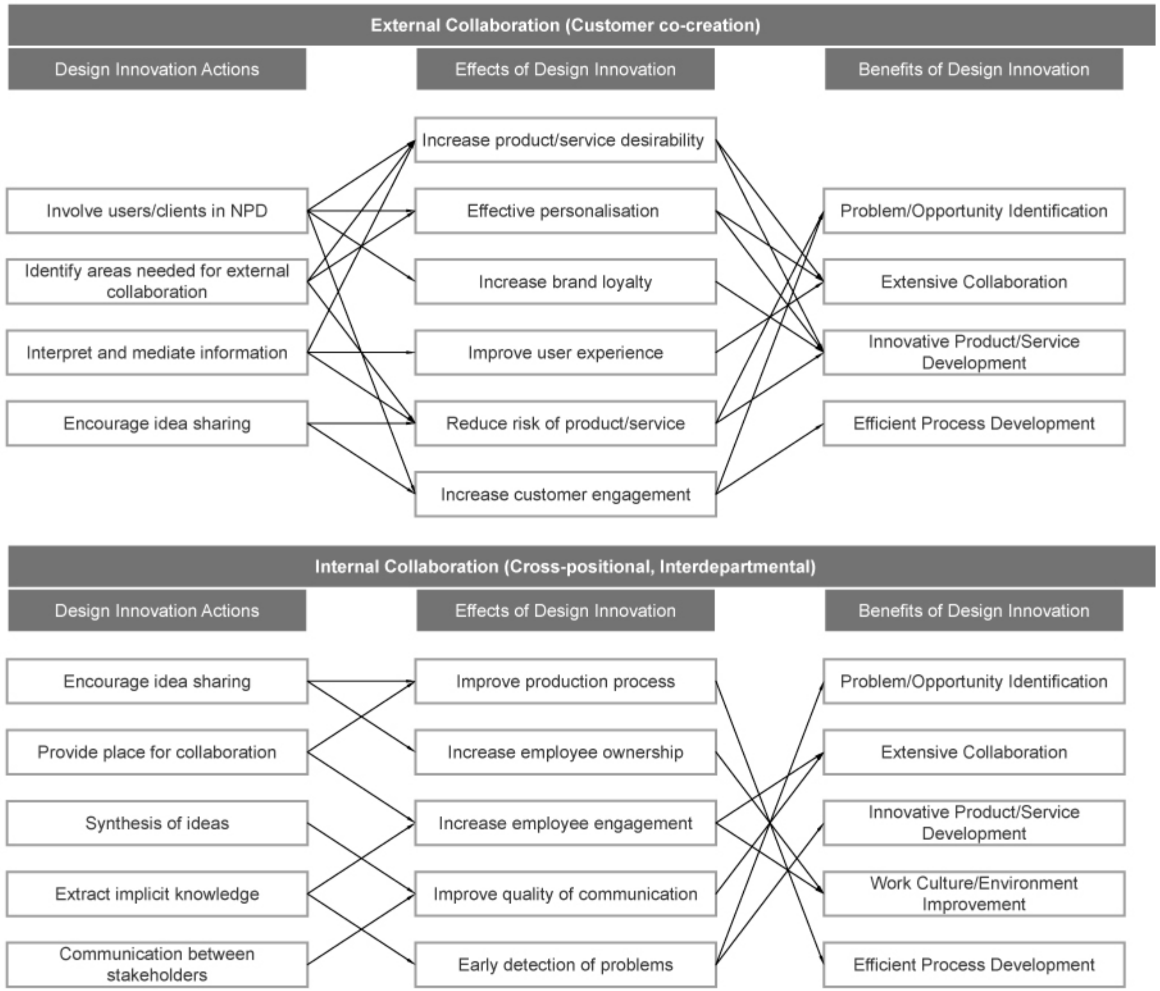
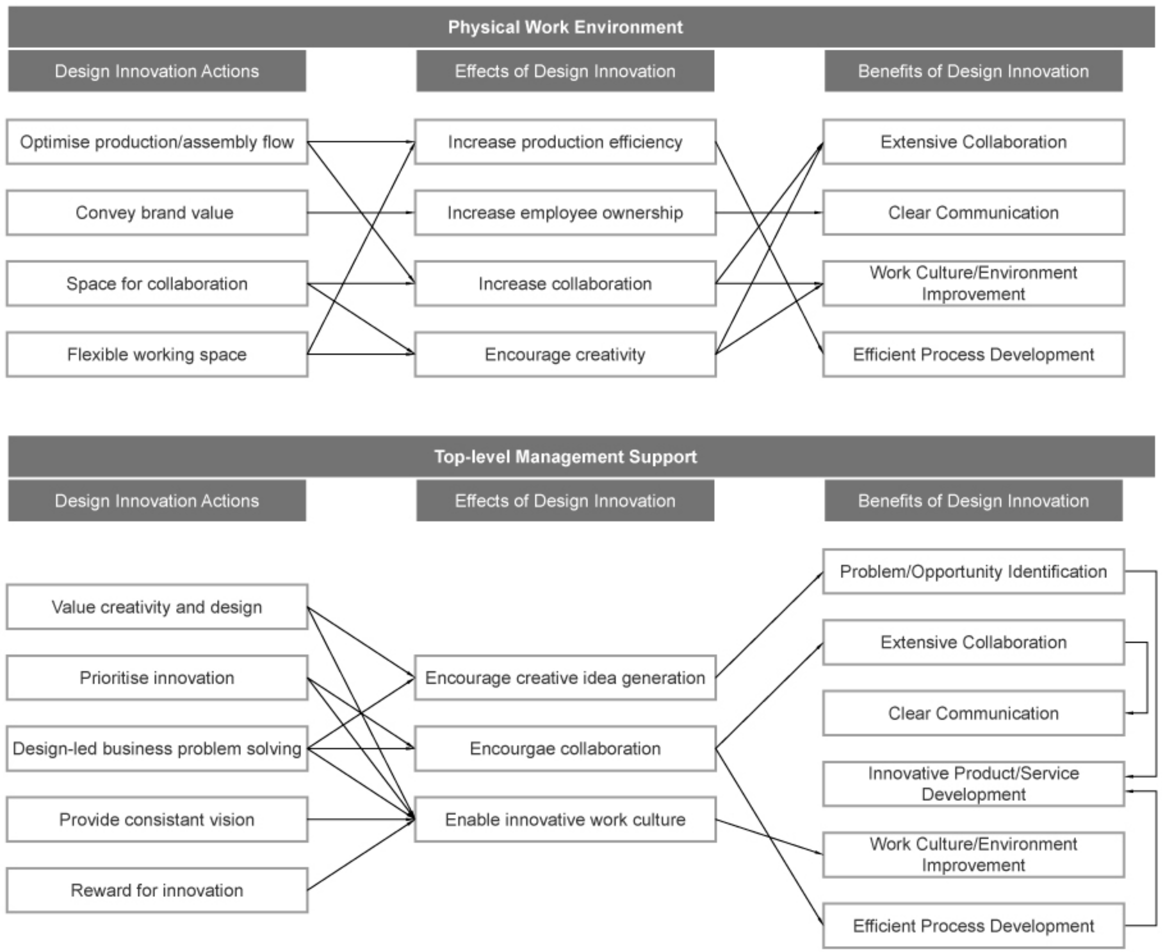
Design Innovation Characteristics: Actions, Effects and Benefits



Design Innovation Characteristics: Actions, Effects and Benefits



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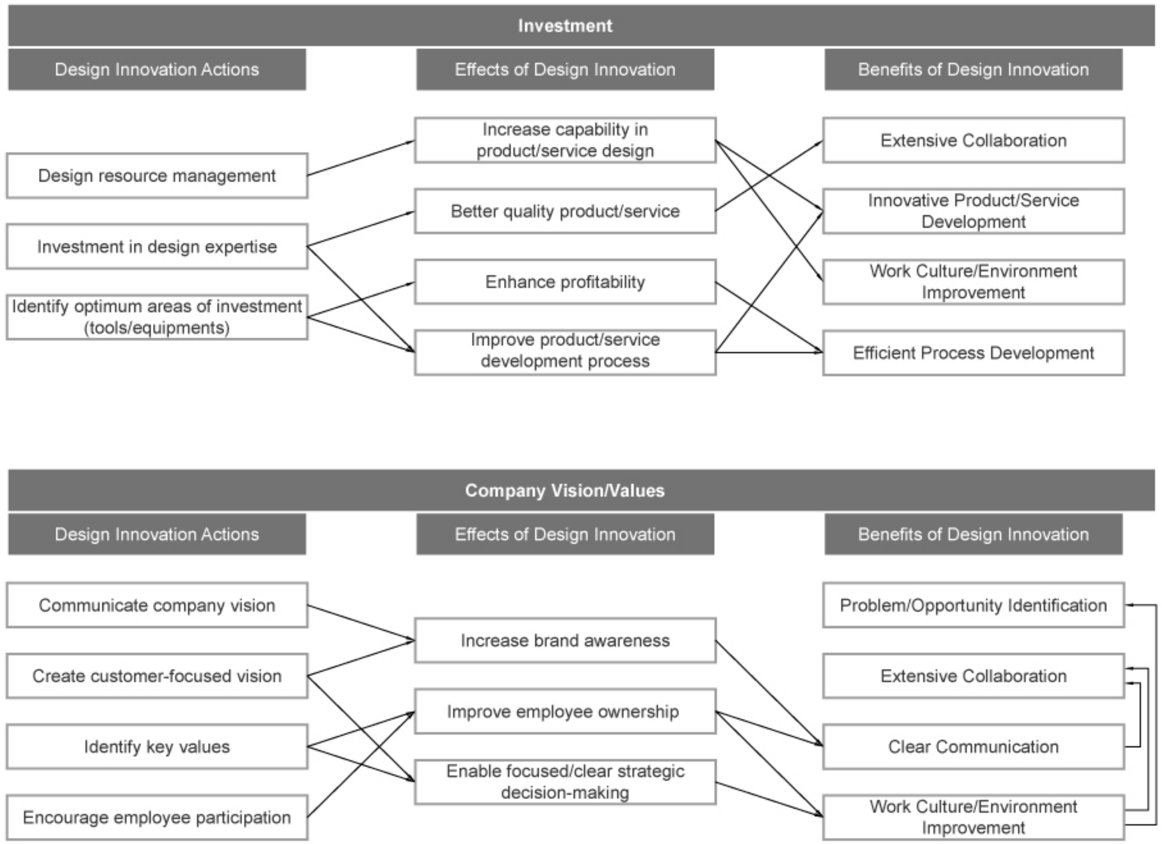
Design Innovation Characteristics: Actions, Effects and Benefits



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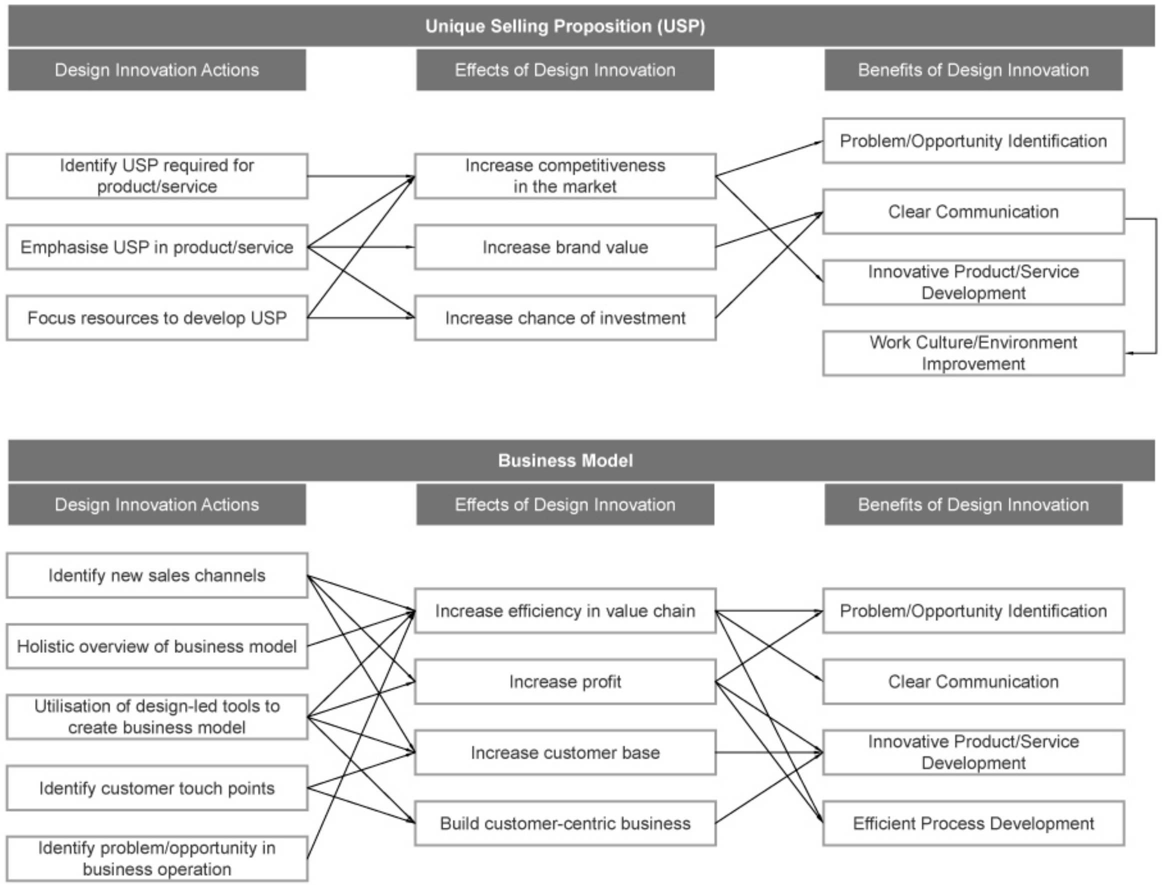
Design Innovation Characteristics: Actions, Effects and Benefits



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APPENDIX H:

Design Innovation Framework booklet (Final version)

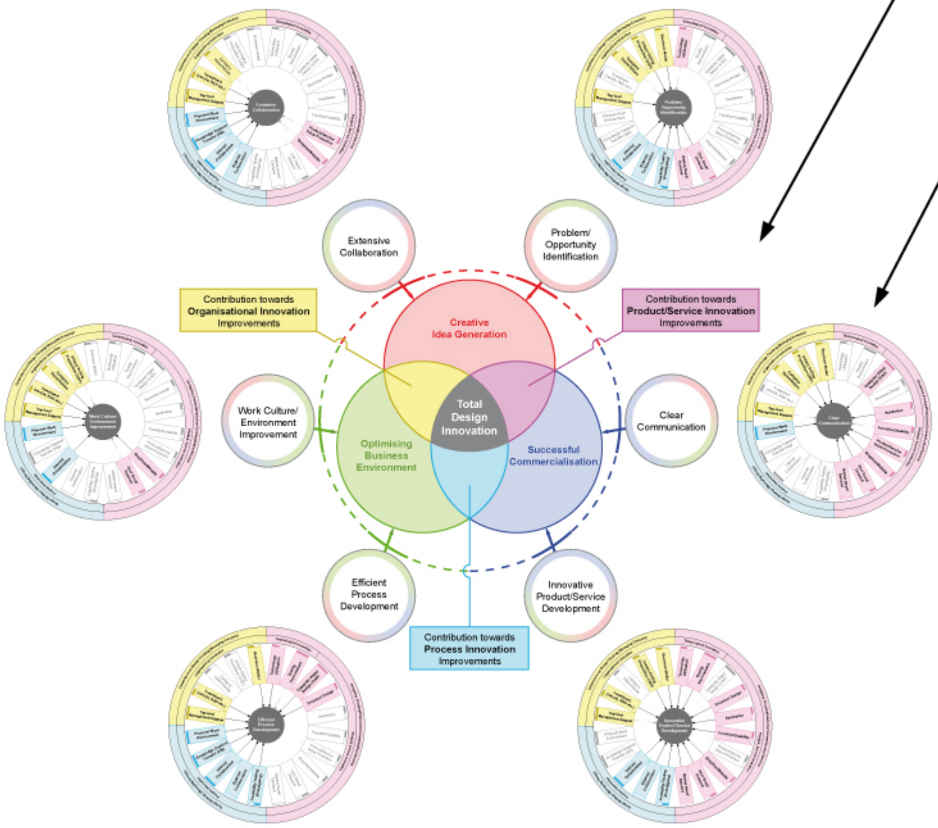
NOTE:

Design Innovation Characteristics: Actions, Effects and Benefits are same as the beta version in Appendix G (booklet pages between 18 to 27), therefore omitted from the final version of the Design Innovation Framework.

Design Innovation Framework

Table of Contents

Design Innovation Framework Overview



	Pages
Design Innovation Framework: Comprehensive overview of design innovation to increase innovativeness.	3
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Implementation Process: Recommendation of how design innovation framework can be used in a commercial context.	9
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1

Introduction to Design Innovation Framework

The purpose of Design Innovation Framework is to provide a holistic overview of design innovation[1] benefits for innovative manufacturing companies[2] in the UK. It is designed to be used as a guide to identify and further improve technological, product/service, process and organisational innovation of a company by utilising designing, design strategy, and corporate-level design thinking which are part of the Design Innovation Spectrum[3].

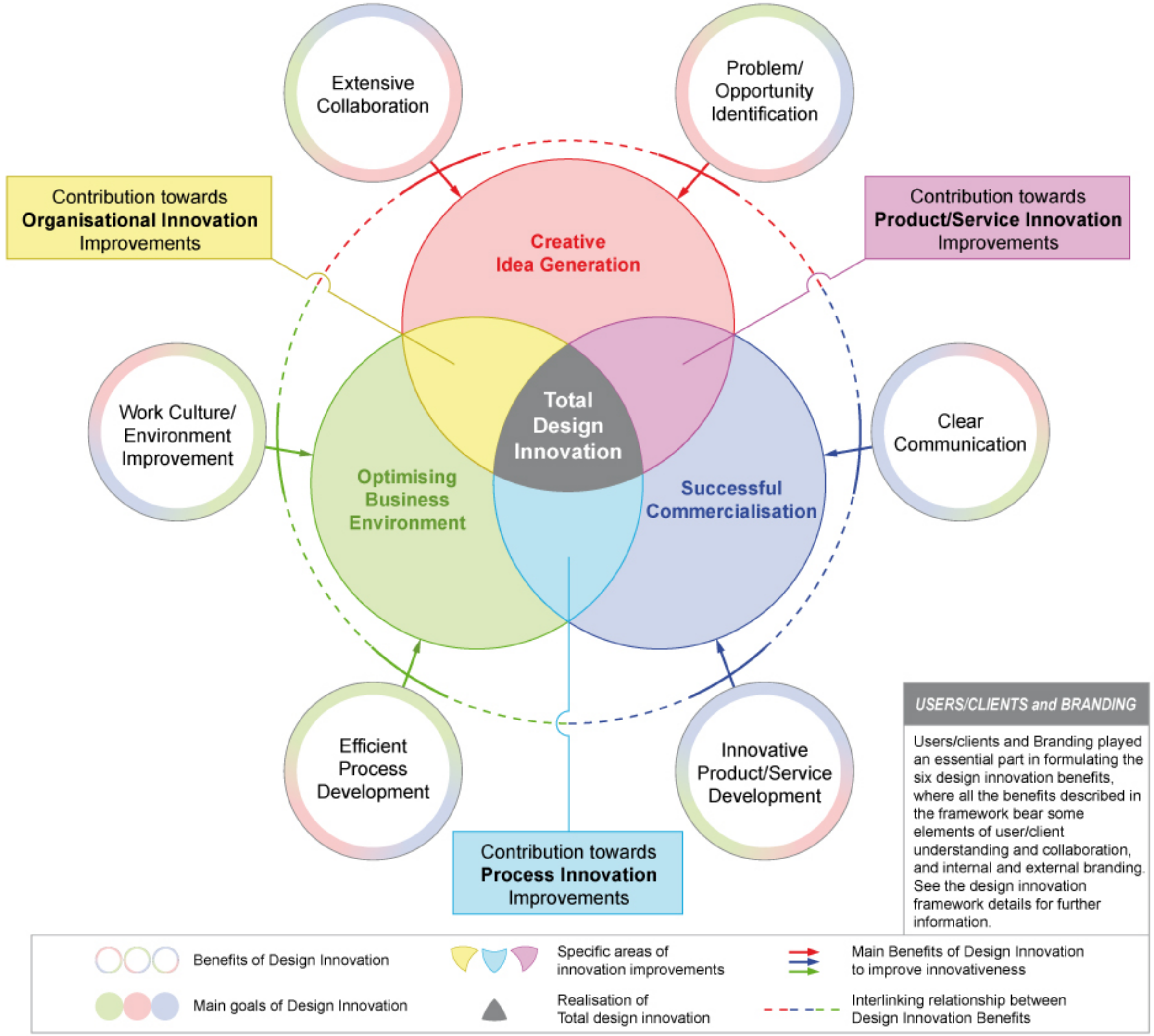
The framework includes 20 characteristics of design innovation which lead to 6 essential benefits for manufacturing companies in order to achieve 3 main goals to improve innovativeness. The Design Innovation characteristics span across the Design Innovation Spectrum, where they help identify design innovation within a company including the influences of design (output) as well as the requirements for design (input). The subsequent six benefits of design innovation are identified from the characteristics which provide improvements that a company can expect by using good design innovation practices. These benefits will help the company to achieve optimisation of business environment, generation of creative ideas, and successful commercialisation. Combinations of these areas will deliver product/service, process and organisational innovation improvements and ultimately enable the company to become a practitioner of ‘total design innovation’ that will increase their global competitiveness.

1 Design Innovation in this research is defined as a creative process and its outcome that enable increased innovativeness of a company through utilisation of full spectrum of design including designing (action to create product/service), design strategy (management of design process), and corporate-level design thinking (philosophy and method of design applied to managing business as a whole). Therefore, the outcome of design innovation can be radical and/or incremental changes in product, service, process, organisational culture, and/or business model.

2 Innovative Manufacturing Company is defined as a commercial organisations within manufacturing sector which recognises the importance of innovation by continuously introducing new or improved products/services, improving production processes, actively seeking for a new market, collaborating with external organisations such as universities, improving ways of working, and/or winning innovation prize(s). The research identified that the innovative manufacturing to be an enabler for advanced manufacturing to expand into high-value manufacturing, however, also a catalyst for other manufacturing companies to increase their competitiveness in the global market.

3 Design Innovation Spectrum is created by thorough literature reviews, and interviews with industry experts both in design and manufacturing fields. It illustrates extensive areas of design and innovation and their relationship. The identified areas are heavily interlinked and hence difficult to separate, however the main areas of ‘design‘ include designing, design strategy, corporate design thinking, and ‘innovation’ areas include technological, product/service/process and organisational innovation (please see page 20).

Design Innovation Framework for Innovative Manufacturing in the UK



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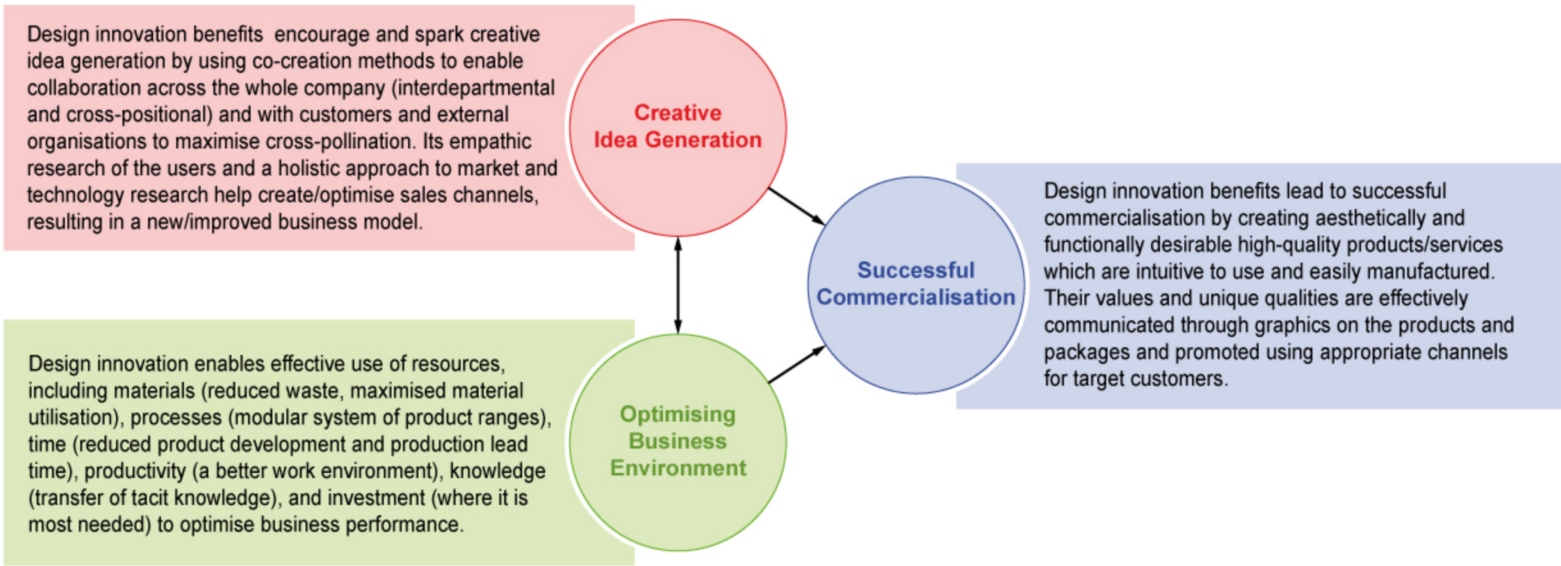
Main Goals of Design Innovation



4

Design Innovation Framework Details

Influence of Design Innovation Characteristics on Creative Idea Generation

Direct Influences of Design Innovation
Indirect Influences of Design Innovation
Design Innovation Characteristics
Benefits of Design Innovation
Design Innovation Spectrum (see page 20)
Internal Research/Data/Action
External Research/Data/Action
Internal & External Research/Data/Action

Note: The direct and indirect influences of the design innovation characteristics shown here represent the influence of the most likely characteristics identified by this research. For further details of the characteristics, see page 8.

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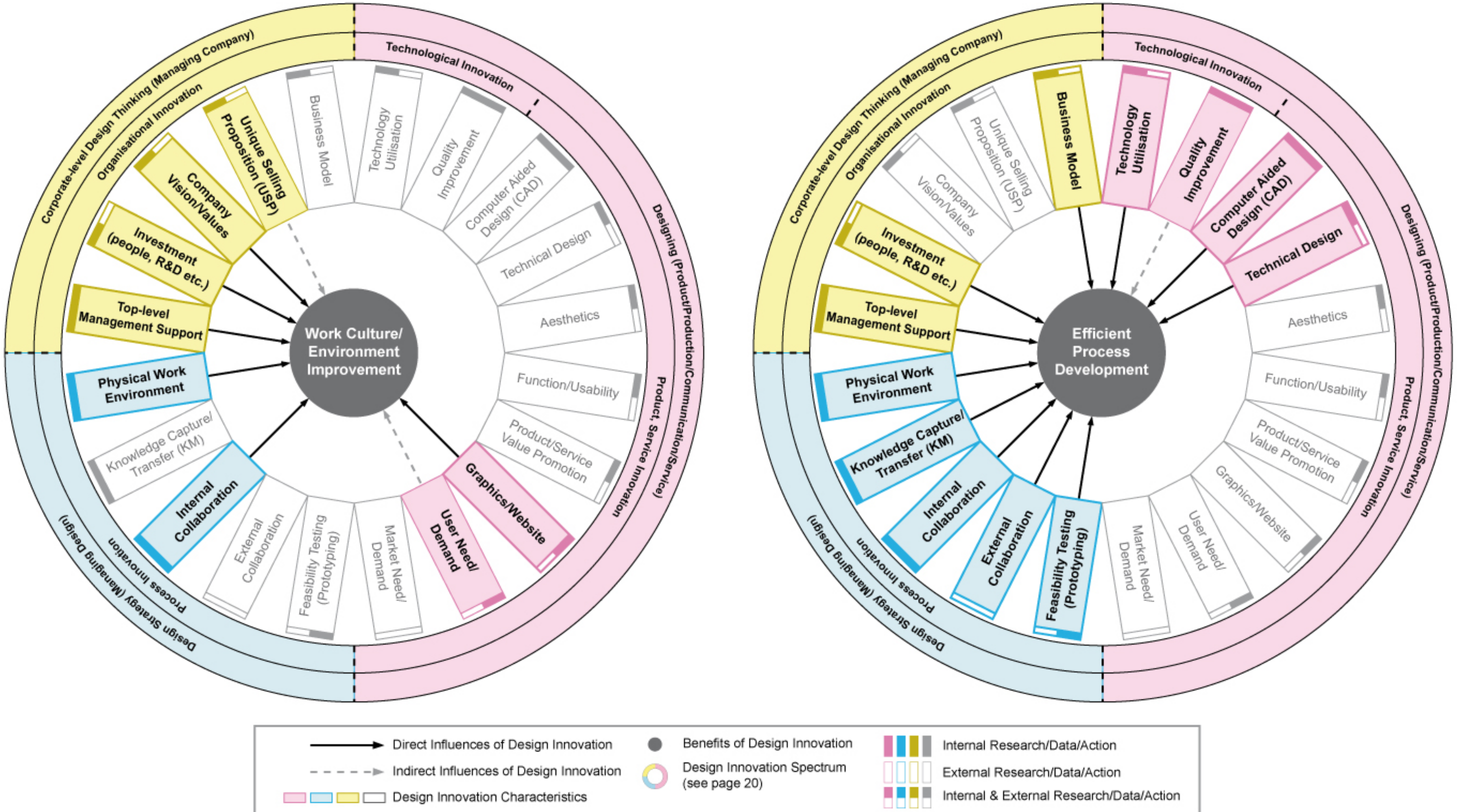
Design Innovation Framework Details

Influence of Design Innovation Characteristics on Optimising Business Environment



Note: The direct and indirect influences of the design innovation characteristics shown here represent the influence of the most likely characteristics identified by this research. For further details of the characteristics, see page 8.

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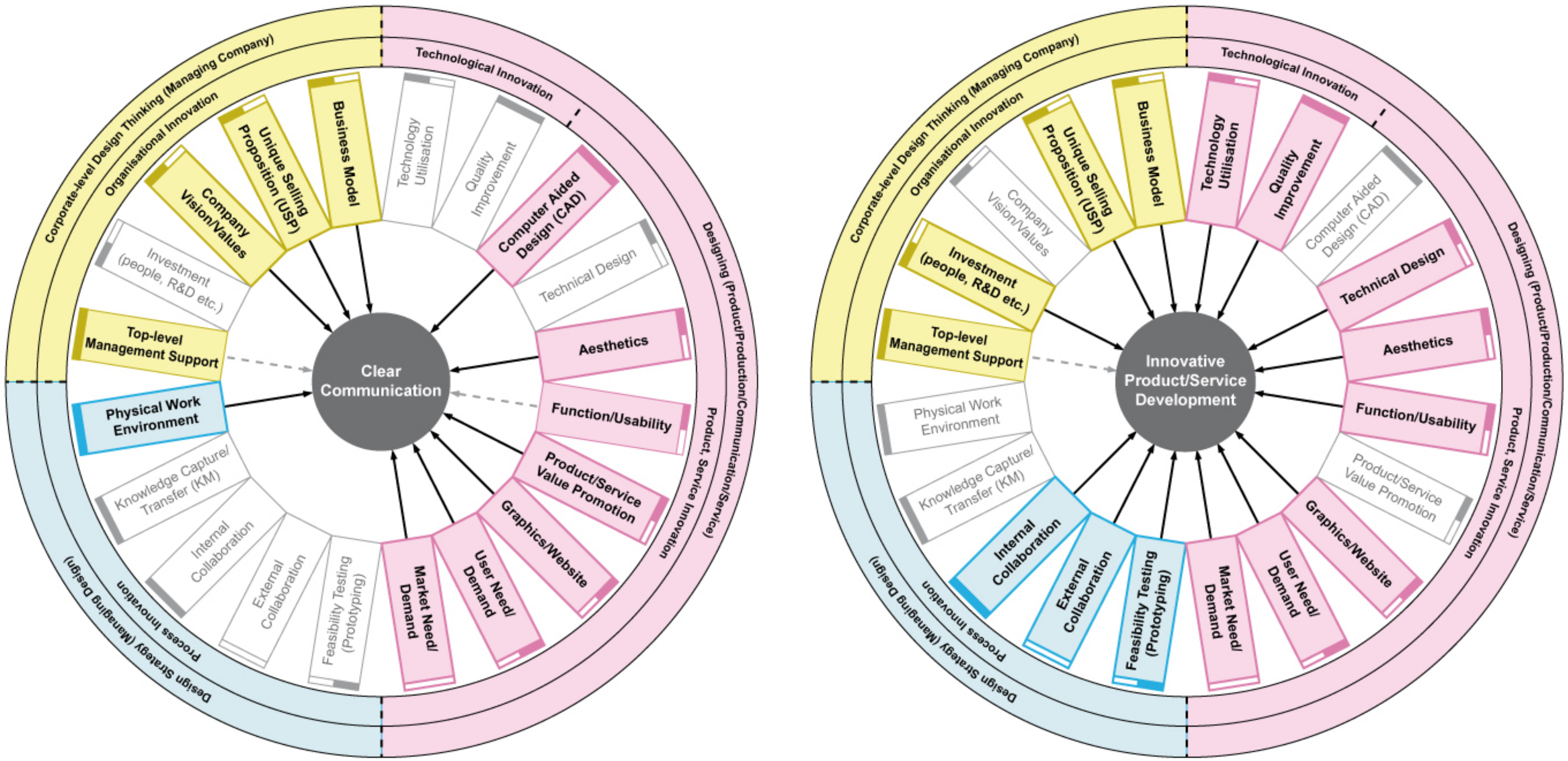
Design Innovation Framework Details

Influence of Design Innovation Characteristics on Successful Commercialisation



Direct Influences of Design Innovation
Indirect Influences of Design Innovation
Design Innovation Characteristics
Benefits of Design Innovation
Design Innovation Spectrum (see page 20)
Internal Research/Data/Action
External Research/Data/Action
Internal & External Research/Data/Action

Note: The direct and indirect influences of the design innovation characteristics shown here represent the influence of the most likely characteristics identified by this research. For further details of the characteristics, see page 8.

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Design Innovation Characteristic Description

Characteristics	Descriptions	Details (page)
Technology Utilisation	Holistic scanning and capturing technological developments in and out of the company to be used in products/services	21
Quality Improvement	Ensuring development of high quality products both technically (help reduce failure and increase effective production) and visually(perception of high quality)	21
Computer Aided Design (CAD)	Utilisation of CAD/CAM to enable effective visualisation and virtual prototyping leading to flexible manufacturing	22
Technical Design	Optimisation of the functions of products and the components for effective production and assembly (DFM/A)	22
Aesthetics	Increasing desirability of products/services for emotional added value for the customers	23
Function/Usability	Ensuring appropriate functions and measures are embedded within products/services that are intuitive to use and easy to maintain	23
Product/Service Value Promotion	Effective communication of the value of products/services to customers and potential customers as well as to employees	24
Graphics/Website	Utilisation of creative graphics on (including UI) and around (packaging and promotional materials, websites) the product/services	24
User Need/Demand	Understanding and empathy of customers to identify their need and demand for existing and potential new products/services	25
Market Need/Demand	Holistic scanning of the current market to identify need and demand and scouting for potential new market to exploit (inc. exports)	25
Feasibility Testing (Prototyping)	Early and frequent prototyping to test feasibility for both form and function as well as for manufacturability of products/services to minimise risk of failure	26
Knowledge Capture/Transfer (KM)	Ensuring appropriate tacit knowledge (experience of the employees) are captured (often digitally) and transferred on demand	26
External Collaboration (Customer co-creation)	Collaboration with customers, suppliers and external agencies to assist product/service development (co-creation) and allow customisation both on product and process (open innovation)	27
Internal collaboration (Cross-positional, Interdepartmental)	Breaking of hierarchical barriers within a company by increasing effective internal communication, and encouraging collaboration between departments to share insights to enable cross-pollination	27
Top-level Management Support	Appreciation of the importance of design innovation by the top-level management with design innovation champions within a company to encourage company-wide design adaptation	28
Physical Work Environment	Create work environment (physical) that is exciting to work in and one that encourages collaboration	28
Investment (HR, R&D etc)	Holistic analysis of the areas that require more resources in order to enable innovation culture and invest or help secure external investments	29
Company Vision/Values	Creation of shared vision and values of a company and enable effective communication to the employees to encourage employee ownership and dedication	29
Unique Selling Proposition (USP)	Identification or creation of the USP of products/services and the company itself to differentiate in the competitive market	30
Business Model	Evaluation of current sales channels and overall business practices to identify improvements or to create more effective channels to maximise profit and customer reach	30

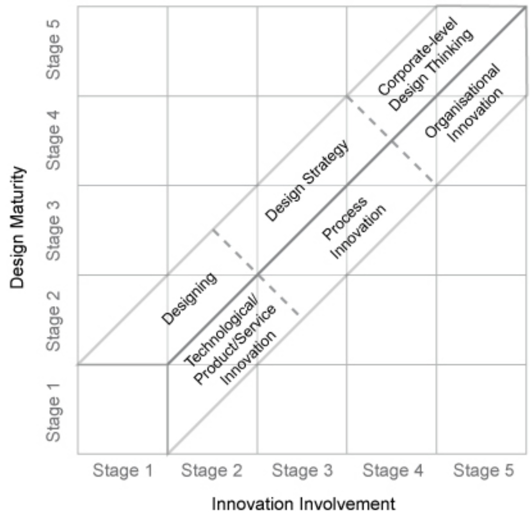
Design Innovation Framework Implementation Process

Introduction

Every company has different problems with varying priorities and circumstances, so there is no universal solution for generating, developing and disseminating innovation with different levels of design innovation adaptation or maturity. The varying situations and strategies of individual manufacturing companies present implementation challenging, as different companies will require different areas of focus to effectively increase their innovativeness.

A generic implementation process for the design innovation framework is therefore recommended. Three Scenarios are provided to give a context for implementing the design innovation framework, which is constructed using the forty-six innovative manufacturing company case studies, searching for common situations likely to initiate design innovation framework implementation. Whilst running a business environment scanning, they would have conducted a design maturity and innovation involvement assessment to place their company within Design Innovation Matrix.

Design Innovation Matrix
(Design Maturity, Innovation Involvement and Design Innovation Spectrum)



	Design Maturity	Innovation Involvement
Stage 1	No Design- Design plays no role in product/service development	Little or no systematic innovative involvement
Stage 2	Design as Styling- Design is only relevant in terms of style	Some systematic innovative involvement in parts of organisation
Stage 3	Design as Process- Design is integral to the development process	Aligning strategic goals with systematic innovation
Stage 4	Design as Strategy- Design is a key strategic means of encouraging innovation	Internally initiated, open-ended learning innovative involvement
Stage 5	Design as Culture- Design thinking practiced in all levels of business	Innovative involvement as a dominant culture

Design Innovation Framework Implementation Process

Further development in the Design Innovation Framework for Total design innovation

Acknowledgement of Problem/Opportunity	Business Environment Scanning	Review Mission and Vision Statements	Benchmarking	Identify Design Innovation Characteristics to Develop	Create Programme and Allocate Budget	Evaluate Outcome
Business problems such as decreasing sales and increasing competition, stale business, or opportunities through new technology development are acknowledged.	Understand the position of the company and its products/services in the current market. Prioritise the core area to develop to maximise the company's strengths and reduce weaknesses.	Identify, and revise if necessary, the reason for the company's existence and values it manifests both internally and externally.	Assess the performance level of best practice in the sector (or the company's own desired level) using the six benefits of design innovation.	Using the design innovation framework, identify the priority characteristics and subsequent design innovation actions to be considered in creating a development programme.	Create programmes to deliver the outcome, including timing responsibilities and cost to achieve the target.	Measure the actual outcome of the programmes against objectives, reviewing and amending as necessary.

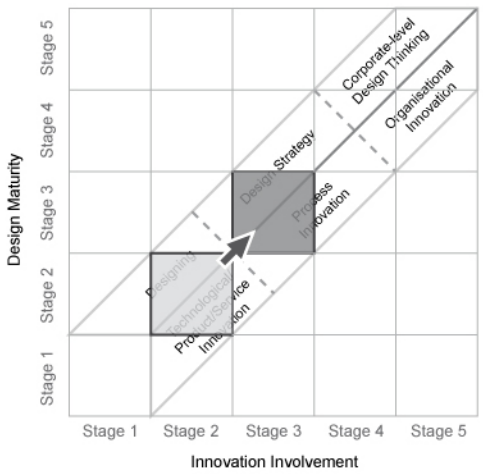
Design Innovation Framework Implementation

Scenario 1: 'Company A' with decreasing market share and customers - Part 1

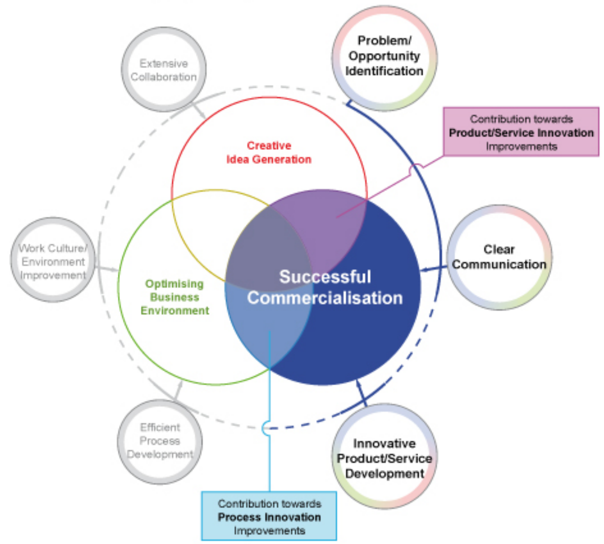
Background

Company A is a manufacturing company which supplies temperature measurement devices for the oil and gas industry to ensure pipelines maintain a constant temperature. The company was founded by a group of researchers with an engineering background when they developed a new technology which can be used in extreme environments with great accuracy and can be produced at relatively low cost. The first product was launched fifteen years ago. The product has been improved over the years for greater accuracy, but competition has increased, especially from overseas companies providing a similar product at lower prices. With declining product sales, the company wants to survive in the market.

Design Innovation Matrix for Company A



Design Innovation Framework with strategic priority in Succesful commercialisation



Design Innovation Framework Implementation Process (Continued on next page)

Acknowledgement of Problem/Opportunity	Business Environment Scanning	Mission and Vision Statements	Benchmarking
The founders and top-level managers are aware of falling market share and sales. However, the recent introduction of less sophisticated but cheaper products made by companies in Italy and Brazil have become such a threat that they are starting to lose even the regular clients who are stringently cutting costs because of the global oil price decrease. In an annual strategic meeting, they all agreed the need to increase innovativeness to compete in the market, and decided to hire a design innovation consultancy as recommended by the Business Growth Service (former MAS). The consultancy uses the Design Innovation Framework to assess, advise and deliver better innovation for the company.	Company A's main product is in the late stage of its lifecycle, adoption and sales both declining. The consultants ran a series of workshop sessions with top-level managers and key employees to critically evaluate the company's situation and position using both traditional tools familiar to the stakeholders (SWOT analysis and the Boston Matrix) and some design-led tools (Lovemark and the Design Innovation Matrix). The priority was initially set as 'successful commercialisation' in the Design Innovation Framework, as the most urgent area was survival in the market. The company's core competence was identified as its unique patented technology which accurately measures temperatures at a higher pressure than any of its competitors.	The company had no mission or vision statements, but top-level managers realised the importance of such statements to address company values to both employees and customers. After the workshop with consultants, top-level managers and participating employees from different departments, they created mission and vision statements which represent the company's core competence and values.	The leading company in a similar sector to Company A was identified to benchmark its performance. The performance of six areas of design innovation benefits were identified and compared with Company A's self-assessment. Problem/opportunity identification, clear communication, innovative product/service development, and efficient process developments showed the biggest difference in performance. These areas were therefore chosen for further development and the company's strategic priority was confirmed as 'successful commercialisation' to increase product/service and process innovativeness.

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Design Innovation Framework Implementation

Scenario 1: ‘Company A’ with decreasing market share and customers - Part 2

Detailed charateristics (in grey) to fulfill strategic priorities and to encourage successful commercialisation for the Comany A

Design Innovation Framework Implementation Process (Continued from previous page)

Identify Design Innovation Characteristics and its Elements to Develop	Create Programme and Allocate Budget	Evaluate Outcome
Please see next page for details	The design innovation consultancy has developed a series of programmes for using design to develop the appropriate areas identified as a priority. Not all programmes were executed to keep the development within the budget. The final outcome is a series of products to complement the existing product. An emphasis was advocated on delivering a brand image of quality and technological advancement, using aesthetics and communications for the new products. The products are positioned at the upper end of the market, with expansion to aerospace and defence to increase exports.	Programmes developed using the design innovation framework have been mostly successful. The strategic targets to survive in the market with increasing competition have been satisfied with increased competitiveness by using design innovation elements. Furthermore, a new overseas market has provided the company with much needed cash-flow to invest in other areas of design innovation benefit (creative idea generation) to increase the company’s innovativeness further towards Total design innovation.

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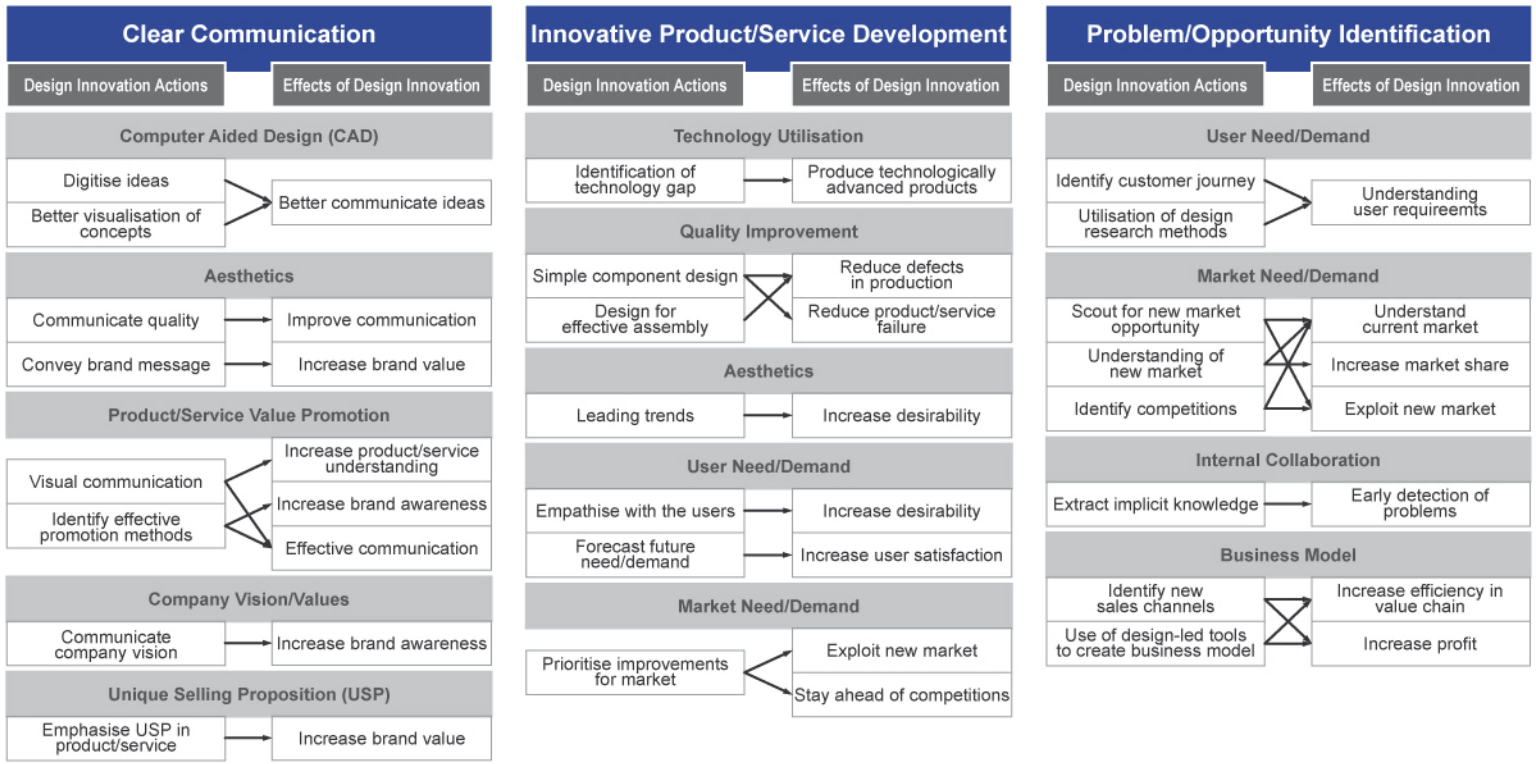
Design Innovation Framework Implementation

Scenario 1: ‘Company A’ with decreasing market share and customers - Part 3

Identified and selected design innovation characteristics and its elements to develop ‘Successful Commercialisation’ for Company A



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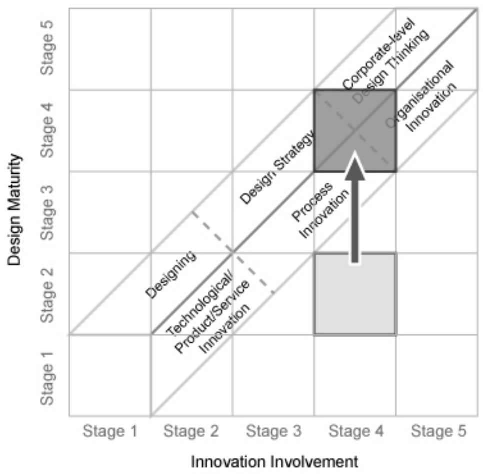
Design Innovation Framework Implementation

Scenario 2: Established ‘Company B’ that wants to expand its business - Part 1

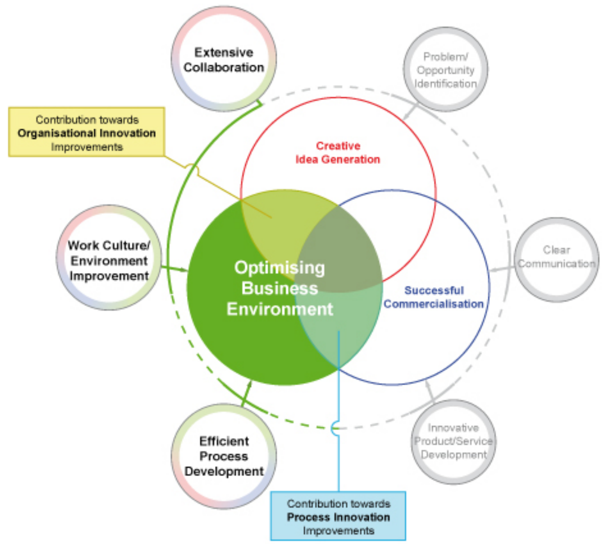
Background

Manufacturing company B has a stable list of clients with solid demand for its products and services. The company, established forty years ago, produces electrical switches for both domestic and commercial use (B2C and B2C) with eighty per cent of its sales in the EU. The company is known for its product reliability with continuing improvements to satisfy current users’ demand. It is also capable of providing bespoke products in small batches and subsequent services to its clients by using a flexible manufacturing method. However, the company directors want to anticipate the fast changing market environment by increasing innovativeness in the company.

Design Innovation Matrix for Company B



Design Innovation Framework with strategic priority in Optimising Business Environment



Design Innovation Framework Implementation Process **(Continued on next page)**

Acknowledgement of Problem/Opportunity

The company has stable cash-flow and revenue, but the top-level managers agree that business has become stale both in the product offerings and in the work culture. They therefore decided to improve their innovativeness to ensure business expansion and anticipate future competition. A dedicated innovation team offers the customer new or improved products every year, but the directors agreed to use the team to develop the process and organisational innovation to increase the company’s profit margins and competitiveness. The innovation team decided to use the Design Innovation Framework to diagnose and improve the company’s innovativeness.

Business Environment Scanning

The innovation team conducted a series of interviews with employees in various departments to understand the work culture and identify areas which could be improved. They found that Company B’s production process has not changed for over twenty years. A large proportion of the shop-floor employees have been with the company for over ten years, but with minimal involvement in the NPD. The design team consists of engineering designers and a product designer, but their involvement in innovation is low, which is represented in the design innovation matrix. The findings were presented in a boardroom meeting, and the directors decided to prioritise ‘optimising business environment’.

Mission and Vision Statements

The company’s mission is to provide reliable light switches which can be used everywhere from domestic homes to space stations, but the mission and vision were not communicated adequately either internally or externally. After a workshop with key employees, directors and external consultants, an additional competence of the company was established, so the mission and vision were altered to reflect the new capabilities.

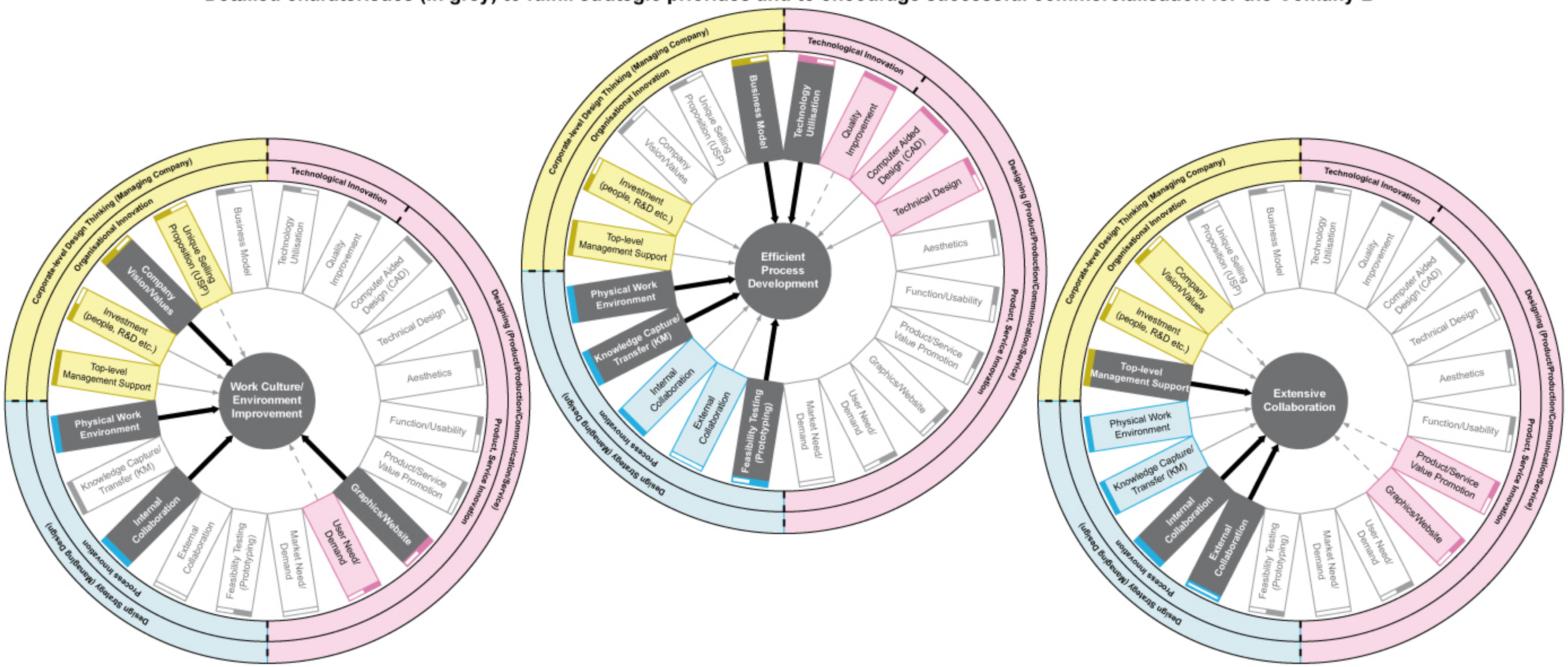
Benchmarking

The innovation team also ran a workshop to understand the market situation, inviting academics in the same sector and consultants who have worked in a similar sector. They benchmarked three companies, one a well-known innovative global company, another a company in a similar sector, and lastly a direct competitor with Company B. As a result of the session, the company decided to prioritise ‘efficient process development’, ‘work culture/ environment improvement’ and ‘extensive collaboration’, led by the innovation team in the first phase of innovation development.

Design Innovation Framework Implementation

Scenario 2: Established ‘Company B’ that wants to expand its business - Part 2

Detailed charateristics (in grey) to fulfill strategic priorities and to encourage successful commercialisation for the Comany B



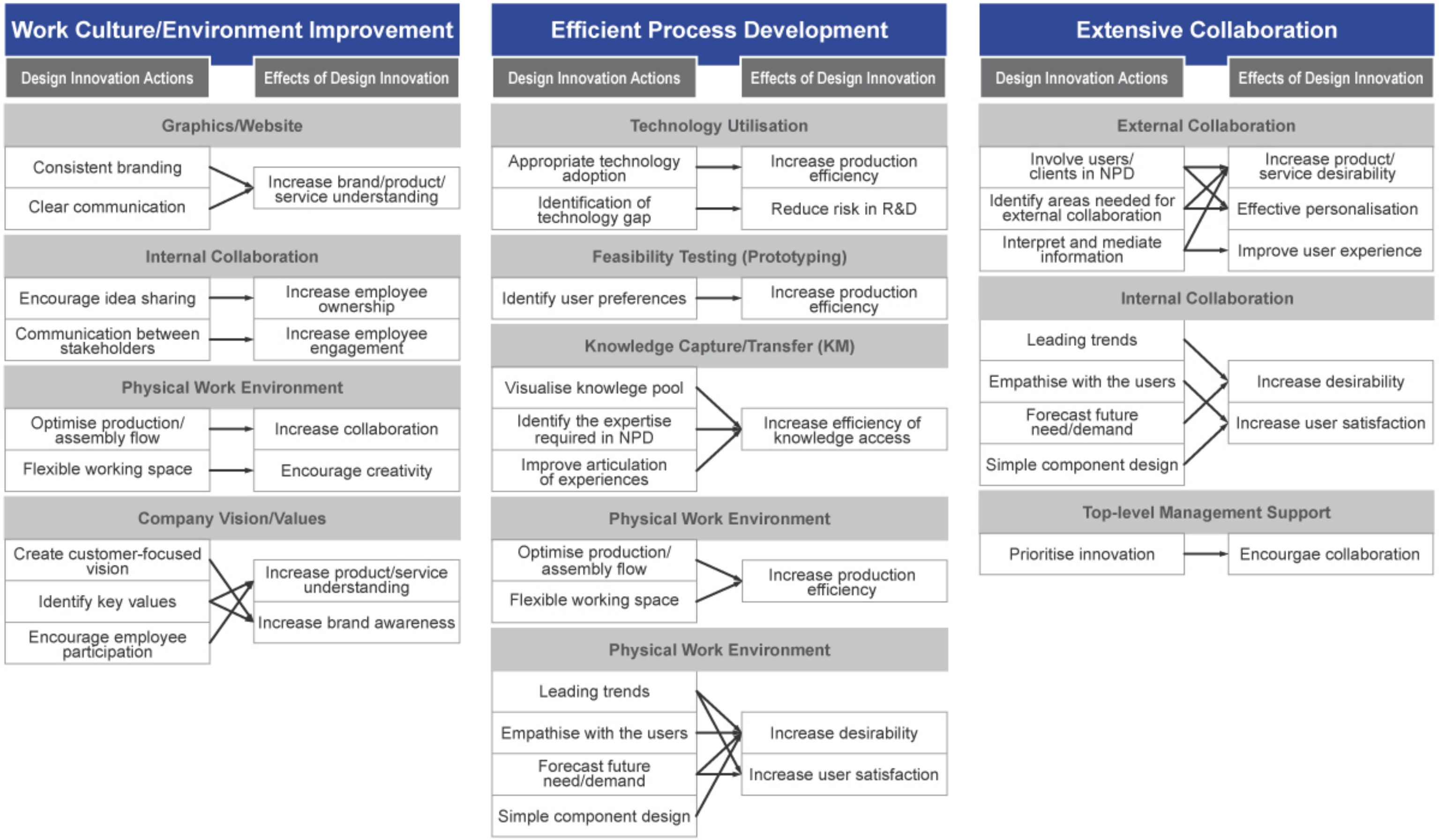
Design Innovation Framework Implementation Process (Continued from previous page)

Identify Design Innovation Characteristics and its Elements to Develop	Create Programme and Allocate Budget	Evaluate Outcome
Please see next page for details	Using the priority design innovation characteristics, briefs were created for design innovation and engineering design agencies. The objectives of the collaboration between the agencies and the innovation team are: (i) review and create a business model to increase profit, (ii) develop internal branding to improve internal company communication (iii) increase employee engagement in NPD and idea-sharing by including collaboration spaces between the shop floor and offices, and (iv) optimise the production process by utilising the latest technology to reduce wasted space and resources.	A design innovation consultancy was hired to work with the innovation team, conducting projects to fulfil objectives (i) and (ii). Internal branding has changed the work culture significantly. Employees are much more satisfied with the work and now share ideas more frequently. Implicit knowledge of more experienced staff is now cross-pollinated in different departments. The company has started a second phase of optimising business (objectives (iii) and (iv)), initiated by collaboration among employees, led by the innovation team.

Design Innovation Framework Implementation

Scenario 2: Established 'Company B' that wants to expand its business - Part 3

Identified and selected design innovation characteristics and its elements to develop 'Successful Commercialisation' for Company B



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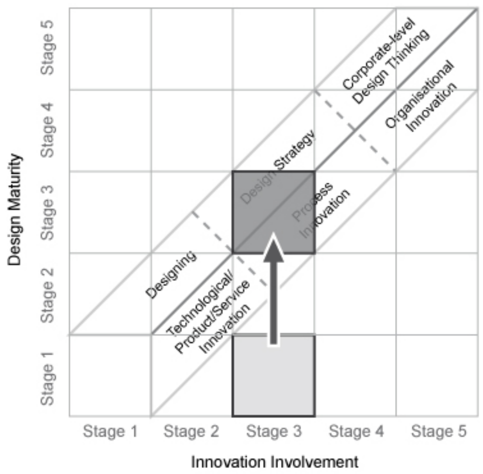
Design Innovation Framework Implementation

Scenario 3: Technology Entrepreneurial Start-up 'Company C' - Part 1

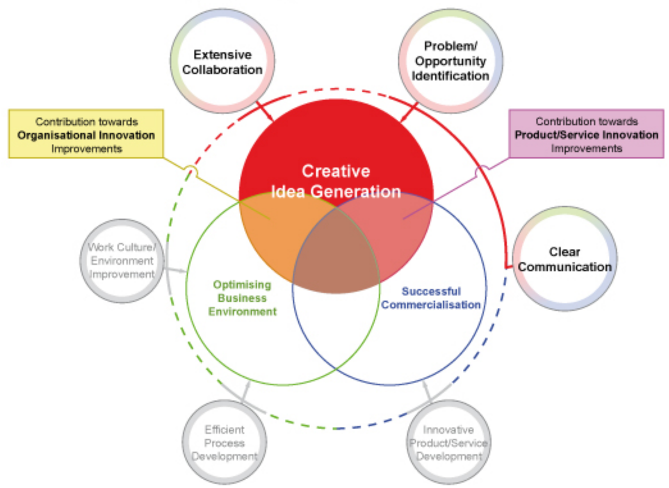
Background

Company C is a start-up manufacturer producing products using technology developed from a university research lab. The core technology is the ability to manipulate specially formulated aluminium alloy power to create 3D objects with high accuracy, using a self-built 3D printer. It produces bespoke parts for Formula One cars and for military application. The company has been given a government start-up grant but requires further investment to continue refining the process to become more widely available. The founders also want the company to adopt total design innovation theory in order to build an innovative business which can lead the market.

Design Innovation Matrix for Company C



Design Innovation Framework with strategic priority in Successful commercialisation



Design Innovation Framework Implementation Process (Continued on next page)

Acknowledgement of Problem/Opportunity

The company founders hope to build a company which excels in innovation, to find new opportunities with the existing in-house technology. As a start-up company, the company operation is very flexible in adopting new approaches but not systematic. The company now works with a university which runs a design innovation boost programme for technology start-ups. The programme uses the Design Innovation Framework to support manufacturing companies to practice Total design innovation which addresses comprehensive design innovation areas to enhance company competitiveness.

Business Environment Scanning

A design innovation consultant was linked with the company by the university support programme. The consultant ran a workshop with Company C founders and employees to identify the company's business environment, using brainstorming and the PESTEL tool. The consultant assessed the company on the design innovation matrix to show the current maturity of design and innovation. The workshop outcome was identifying the company's core competence, both in the technological sense and in how they create the bespoke products demanded by their clients. They also identified their lack of systematic idea generation leading to a new product, because the company only relied on fulfilling client requests to produce bespoke products. The company has therefore decided to initiate the total innovation journey with 'creative idea generation'.

Mission and Vision Statements

The company focus has been technology advancement, but the workshop provided new ideas and possibilities, so the founders identified a new vision for the company: to focus more on cultivating and using creativity to become more innovative in product, service, process and the organisation as a whole. The perception of design has also changed, and they are now considering hiring a design director to lead all the company's design innovation operations.

Benchmarking

A second workshop was held with the consultants and other professionals in the field similar to Company C. Before the workshop, the company founders identified several companies they wanted to benchmark. Some were multinational companies in a different sector and some were some organisations in the same sector. Initial discussions identified the performance level in the six essential benefits of design innovation. Further desk research identified priority areas for the company: 'extensive collaboration', 'problem/opportunity identification', and 'clear communication'.

Design Innovation Framework Implementation

Scenario 3: Technology Entrepreneurial Start-up ‘Company C’ - Part 2

Detailed charateristics (in grey) to fulfill strategic priorities and to encourage successful commercialisation for the Comany C

Design Innovation Framework Implementation Process (Continued from previous page)

Identify Design Innovation Characteristics and its Elements to Develop	Create Programme and Allocate Budget	Evaluate Outcome
Please see next page for details	The company, with support from the consultant, created a strategic plan to develop the priority design innovation characteristics. First they emphasised the company USP and branding and created a business model which was received well by new investors. With the investment, the company hired a new creative director to create design-led programmes in order to understand potential new users and markets and find opportunities. The company has also created set of programmes to enhance creativity in NPD and new service offerings to use its technology in a new market.	The programmes developed through the design innovation framework and university collaboration have made the company more competent at identifying opportunities and delivering products and services which potential users would value. The immediate financial achievement through new investment has helped the company to grow its design innovation capabilities and expand into new markets by understanding the new users. The company now seeks to improve its innovativeness further by developing other design innovation characteristics, working towards becoming a total design innovation company.

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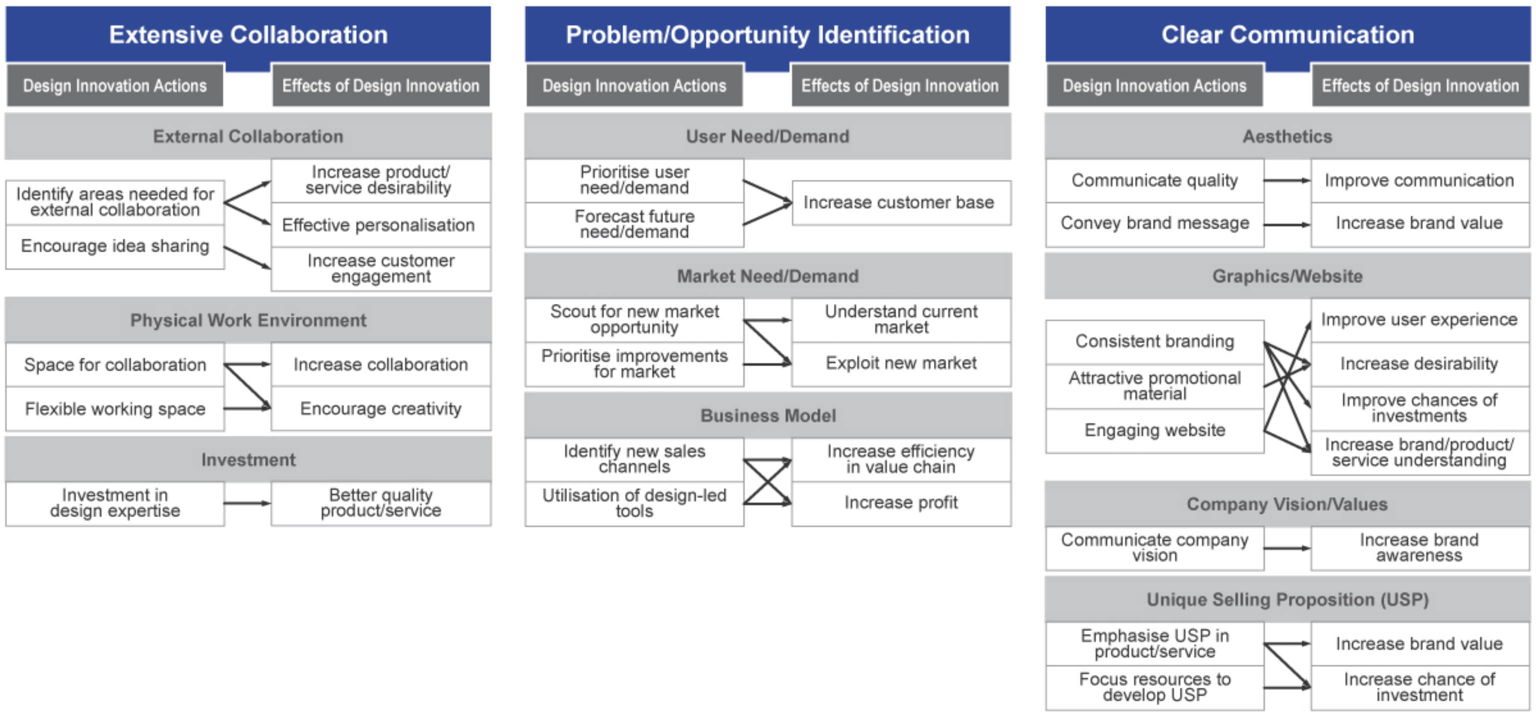
Design Innovation Framework Implementation

Scenario 3: Technology Entrepreneurial Start-up ‘Company C’ - Part 3

Identified and selected design innovation characteristics and its elements to develop ‘Successful Commercialisation’ for Company C



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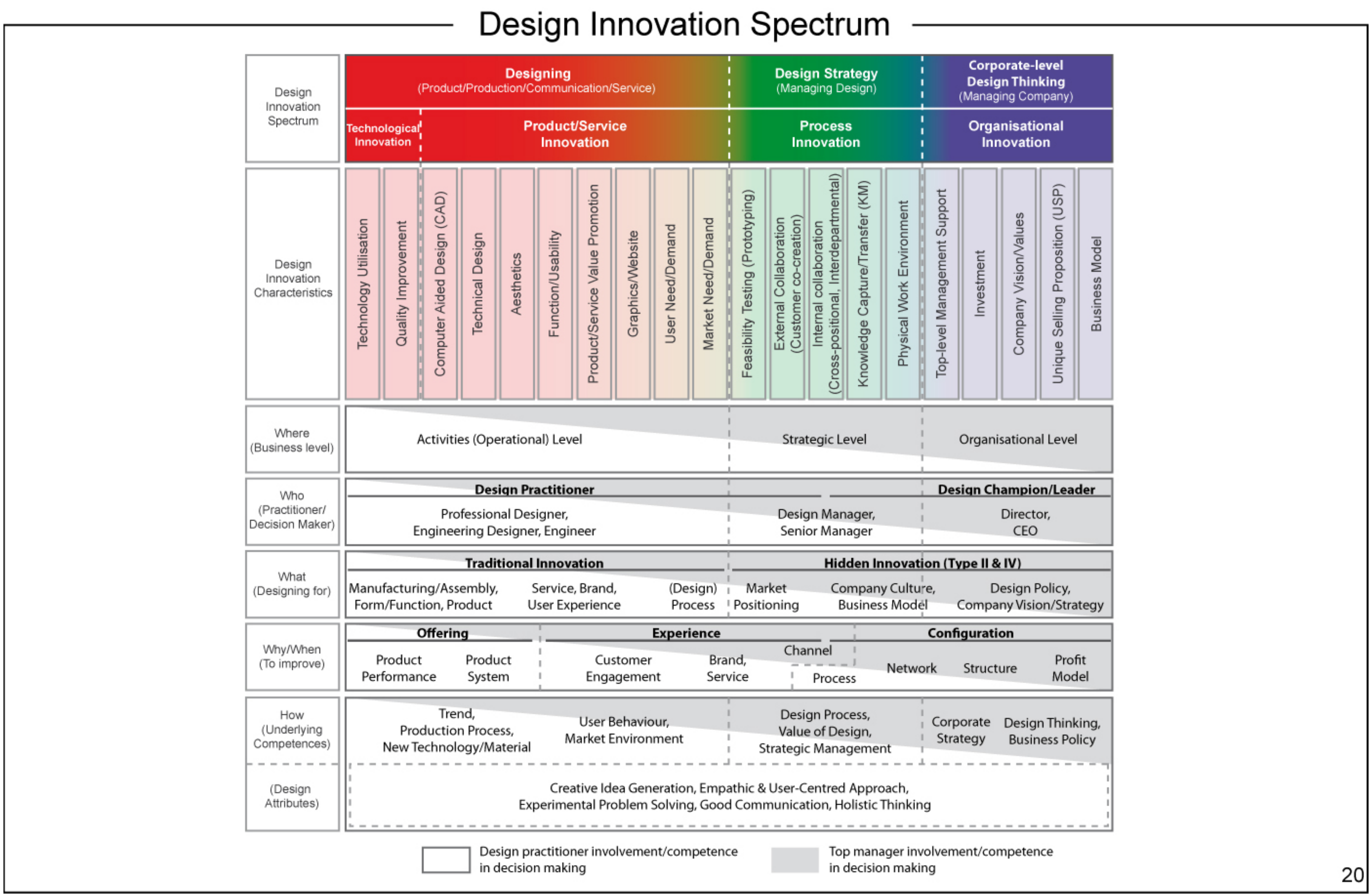
Design Innovation Framework
Further Details


Design Innovation Spectrum
Design Innovation Spectrum
Designing
(Product/Production/Communication/Service)
Design Strategy
(Managing Design)
Corporate-level Design Thinking
(Managing Company)
Technological Innovation
Product/Service Innovation
Process Innovation
Organisational Innovation
Design Innovation Characteristics
Technology Utilisation
Quality Improvement
Computer Aided Design (CAD)
Technical Design
Aesthetics
Function/Usability
Product/Service Value Promotion
Graphics/Website
User Need/Demand
Market Need/Demand
Feasibility Testing (Prototyping)
External Collaboration (Customer co-creation)
Internal collaboration (Cross-positional, Interdepartmental)
Knowledge Capture/Transfer (KM)
Physical Work Environment
Top-level Management Support
Investment
Company Vision/Values
Unique Selling Proposition (USP)
Business Model
Where (Business level)
Activities (Operational) Level
Strategic Level
Organisational Level
Who (Practitioner/ Decision Maker)
Design Practitioner
Design Champion/Leader
Professional Designer, Engineering Designer, Engineer
Design Manager, Senior Manager
Director, CEO
What (Designing for)
Traditional Innovation
Hidden Innovation (Type II & IV)
Manufacturing/Assembly, Form/Function, Product
Service, Brand, User Experience
(Design) Process
Market Positioning
Company Culture, Business Model
Design Policy, Company Vision/Strategy
Why/When (To improve)
Offering
Experience
Configuration
Product Performance
Product System
Customer Engagement
Brand, Service
Channel
Process
Network
Structure
Profit Model
How (Underlying Competences)
Trend, Production Process, New Technology/Material
User Behaviour, Market Environment
Design Process, Value of Design, Strategic Management
Corporate Strategy
Design Thinking, Business Policy
(Design Attributes)
Creative Idea Generation, Empathic & User-Centred Approach, Experimental Problem Solving, Good Communication, Holistic Thinking
Design practitioner involvement/competence in decision making
Top manager involvement/competence in decision making
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Design Innovation Characteristics: Actions, Effects and Benefits

NOTE:

Design Innovation Characteristics: Actions, Effects and Benefits are same as the beta version (page 18-27 of the booklet).
Please see Appendix B