Deploying Process Innovation in Manufacturing

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Abstract

Manufacturing companies are increasingly under pressure to innovate due primarily to the intense competition they face, particularly under global market conditions. Innovation is recognised as a precondition for survival. Implementation of innovative initiatives in manufacturing is an important and challenging phase of process innovation. This is more so in the pre-implementation phase, in which manufacturing organisations need to prepare and be appropriately ready to deploy their process innovation initiative.

This thesis focuses on the methodology of deploying process innovation in manufacturing to identify the factors influencing deployment readiness, evaluate hypothesised influences of some of the factors on deployment readiness, and provide an accessible method of assessing deployment readiness levels. Several important results and significant contributions to knowledge are arising from the research reported in this thesis. The thesis reports on the findings that several factors can influence deployment process innovation which is characterised along the dimensions of context for process innovation, performance, capability and capacity, resources, and collaboration. Through developing and evaluating a conceptual framework for process innovation deployment readiness, the thesis found a significant positive link between process innovation deployment preparedness and being fully ready to deploy. It was also found that having a deployment plan has a significant positive influence on being fully ready to deploy process innovation.

These results have important implications for manufacturing managers, especially regarding the need for a deployment plan, ensuring a good climate for innovation, and being prepared to deploy process innovation in manufacturing. Perspectives of manufacturing managers reported in the thesis indicate that manufacturing companies do not necessarily need to attain a 100% deployment readiness level. On average, the companies appear satisfied with about 70% deployment readiness level. A fuzzy logic method for assessing manufacturing process innovation deployment readiness level presented in this thesis will help manufacturing companies gauge their readiness level and identify areas of improvement should they wish to increase their deployment readiness level prior to implementation. The method was validated in a case study company and found useful. The thesis concludes by reinforcing the need for manufacturing companies to rely more on appropriate techniques, such as those arising from this research, for use in successfully managing the deployment of their process innovation initiatives.

List of Publications

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Acronym

1 Introduction

1.1 Research Motivation

Intensive competition in the global market has made innovation a pre-condition for survival for manufacturing companies. Therefore, there is increasing pressure on companies, both from within and outside, to continuously innovate their products and processes. Thus, it is not unusual to see manufacturing companies invest in the innovation of their products and processes to increase their profitability, enhance their competitive advantage, and consolidate their overall position in their sector.

Innovation, in general, is a new or considerably improved product (good or service), or process, a new method of marketing or a new approach in business, workplace organization or external relations (Schumpeter, 1934). De Jong, (2006) expresses innovation as creating new ideas, products and processes and their effects on the organization's performance. The view that innovation is a condition for survival in manufacturing cannot be overemphasised (Cefis and Marsili, 2006; Gonçalves Silveira Fiates et al., 2010). Manufacturing companies can derive benefits from innovation through the mechanisms it offers for adapting to the demands of dynamic environments (Hurley & Hult, 1998). Having the capacity and capability to innovate coupled with innovation implementation efficiency, amongst others, influences a manufacturing company's ability to compete over time (Abernathy, 1978; Stalk and Hout, 1990; Rajapathirana and Hui, 2017).

To be competitive, manufacturing companies need to ensure ongoing interaction between operations and incremental improvement aimed at effectively combining process and operational effectiveness, strategic flexibility and learning. Manufacturing companies that engage in ongoing upgrades or enhancements of existing technologies, processes or products are continuously innovative. Such companies will have the ability to change their business or management model as well as to develop, adopt, and implement new products, processes and technologies that respond to customer needs.

Product innovation and process innovation are two of the key dimensions of innovation in manufacturing. Product innovation refers to new and/or improved products, equipment, and service whilst process innovation is the development of an organization's production or service operations, input materials, task specifications, work and information flow mechanisms, and equipment through the introduction of new elements including new technologies and new practices. The two, i.e., product innovation and process innovation, are not mutually exclusive.

An important facet of competitive advantage in the manufacturing of interest in this thesis is process innovation. The importance of process innovation has been demonstrated in a variety of studies, including, for example, the introduction of new technology for shop floor data collection (Chuang and Shaw, 2008), lean philosophy adoption (Lins et al., 2019), and Cloud-based ERP adoption (AlBar and Hoque, 2019). Innovativeness is seen as an enabler and key consideration in sustainable and smart manufacturing processes (Sjödin, Parida, Leksell, & Petrovic, 2018). Transitions to higher levels of lean attainment demand process innovation thinking (Sanchez and Sunmola, 2017).

In the context of manufacturing, manufacturing process innovation (MPI) has been expressed in a variety of ways, including as 'an organization-wide effort that involves fundamental rethinking and radical redesign of manufacturing-related processes and systems to achieve dramatic improvements in manufacturing performance measures such as cost, quality, service, and speed (Hammer and Champy, 1993). In MPI, innovation may not be limited only to processes but could include operations and all activities involved in the product transformation process ranging from raw-material acquisition to supply of new products. Also covered are support systems such as production planning, logistics, purchasing, administration, engineering, and management.

The consequences of successful manufacturing process innovation include financial performance, market performance, competitive advantage, environmental performance, and employee performance (Tariq et al., 2017). As with most things, successful innovation of manufacturing processes demands, amongst other things, preparedness and achieving an appropriate deployment readiness level prior to implementing the innovation initiative in a manufacturing environment. Preparing for deployment is a key step in implementing process innovation initiatives. Preparation for deployment is usually considered a part of the pre-implementation phase of putting a process innovation implementation decision into effect (Razmi et al., 2009). Enterprises that fail to deliver process innovation successfully are typically those that do not meet an appropriate level of readiness to deploy (Ahmadi et al., 2015; Alireza and Sunmola, 2017). The manufacturing industry will benefit from research that provides increased knowledge and understanding of how to go about deploying process innovation initiatives. This is the primary motivation for the research documented in this thesis. The following section, Section 1.2. presents an overview of the thesis, particularly the aims and objectives of the research reported in the thesis (Section 1.2.1) and the contribution of the thesis (Section 1.2.2). This chapter ends in Section 1.3 with an overview of the thesis structure.

1.2 About this thesis

Manufacturing companies will not be able to get the full benefits and returns on their process innovation investments if they do not attain appropriate levels of readiness to deploy their innovation initiatives. The issues around this basically relate to clarity regarding the methodology of deploying manufacturing process innovation initiatives and the availability of requisite methods, tools, and techniques for effecting the deployment.

A preliminary exploration of related studies suggests that the methodology of process innovation deployment for manufacturing companies would, amongst others, necessarily include a) clarity of the factors involved in the deployment process, b) the influences of the factors on readiness to deploy, and c) a method of accessing how ready a company is regarding deployment of their process innovation initiative. There are knowledge gaps around these three essential aspects of deploying process innovation in manufacturing, and the gaps are explained further in this thesis. The highlighted knowledge gaps are the focus of this thesis. The research aims and objectives are stated in the next section, Section 1.2.1 below.

1.2.1 Research Aims and Objectives

The aims of this research are a) to investigate factors associated with readiness to deploy process innovation in manufacturing and b) to synthesise and evaluate how the factors can support achieving readiness to deploy manufacturing process innovation initiatives. The objectives of the research are as follows:

1) Identify through a traditional literature review the main attributes associated with readiness to deploy process innovation.
2) Determine the factors that influence readiness to deploy process innovation in manufacturing through a Delphi study that builds on the related attributes found in the literature.
3) Design a configuration of attributes, factors and dimensions of process innovation deployment readiness that can be used as a basis for understanding and organising assessment information regarding the deployment process.
4) To develop and evaluate a conceptual framework for use in explaining the phenomenon of process innovation deployment readiness in manufacturing and establishing the influences of the constructs in the conceptual framework on deployment readiness levels, i.e., the extent to which a company is ready to deploy its process innovation initiative.
5) To develop, and illustrate through a case study, an accessible method of assessing process innovation deployment levels in manufacturing which leverages the configuration of attributes, factors and dimensions of process innovation deployment readiness put forward in the thesis.

1.2.2 Contributions of this thesis

In achieving the research aims and objectives set out in Section 1.2.1 above, significant contributions to knowledge and practice are made by putting forward requisite knowledge and understanding of manufacturing process innovation deployments, particularly from a perspective on the factors influencing deployment levels and the application of the factors in the assessment of manufacturing process innovation deployment readiness.

The thesis contributes to knowledge and practice in a variety of ways. Using experts in the manufacturing industry, a useful set of attributes, factors, and dimensions of process innovation deployment readiness are developed and configured for use in a continuous improvement setting for process innovation implementation. It is found that process innovation deployment readiness can be influenced by several factors, namely, absorptive capacity, deployment control, deployment coordination, deployment plan, dynamic capability, external factors, resources (financial and human), flexibility, context (innovation context, organisational and leadership context), and performance expectations. The thesis characterised the factors along the dimensions of context for process innovation, performance, capability and capacity, resources, and collaboration. The influence of a set of constructs of process innovation deployment readiness was put forward alongside hypothesised influences of the factors on deployment readiness states. This thesis introduced the notion of preparedness as an important state in the readiness to deploy process innovation in manufacturing and shows that to be fully ready for process innovation deployment, it is important to be prepared. It also ascertains that having a deployment plan positively influences being fully ready to deploy process innovation. It also contributes to our understanding of manufacturing flexibility, noting that labour flexibility has a significant positive influence on preparedness to implement process innovation, but such a result was not supported for mix flexibility.

A method of assessing manufacturing process innovation deployment readiness level is put forward in the thesis. The method uses fuzzy logic and is based on an assessment template that is composed of attributes, factors, and dimensions of manufacturing process innovation derived in the thesis. A key contribution of the assessment method is its accessibility, evidenced by the result of a case study reported in the thesis. The fuzzy logic approach permits the use of linguistic variables and linguistic values in the assessment of manufacturing process innovation deployment readiness levels. Linguistic variables are very useful for handling situations, including complex situations which are difficult to define well quantitatively, akin to what is found when attempting to assess manufacturing deployment readiness level. An attractive feature of the assessment method presented is easy, which can be integrated into a continuous improvement framework by identifying areas for which deployment readiness levels can be improved.

These contributions have important implications for manufacturing managers, especially regarding the need for a deployment plan, ensuring a good climate for innovation, and being prepared to deploy process innovation in manufacturing. Perspectives of manufacturing managers reported in the thesis indicate that manufacturing companies do not necessarily need to attain a 100% deployment readiness level. On average, the companies appear to be satisfied with about 70% deployment readiness level. Even in this scenario of less than 100% deployment readiness will do, the contributions of this thesis can be geared towards achieving appropriate deployment readiness more effectively.

1.3 Structure of the Thesis

The remainder of this thesis is structured into six main chapters. Chapter 2 contains a literature review on topics relevant to the research. They include the concept of innovation, innovation processes and associated models, manufacturing process innovation, deployment readiness and associated models, and finally, attributes of deployment readiness. In Chapter 3, the research methodology adopted in the thesis is presented, covering traditional literature review of related work, questionnaire-based survey, Delphi study, Fuzzy Logic, and Case studies method. Chapter 4 presents the consolidated attributes, factors and dimensions of manufacturing process innovation deployment readiness and describes the Delphi method adopted to arrive at the consolidated list. Chapter 5 contains the conceptual framework developed in the thesis to explain the influences of some important constructs on readiness to deploy process innovation in manufacturing. Also contained in Chapter 5 is an evaluation of the conceptual framework using data collected from a questionnaire survey. Chapter 6 contains the description of the fuzzy assessment method put forward in this thesis for assessing manufacturing process innovation deployment readiness. Chapter 6 also contains a case study that illustrates and validates the fuzzy assessment method. Finally, the thesis ends in chapter 7 with conclusions and suggestions for future work.

2 Literature Review

2.1 Introduction

In the global market, intensive competition has brought to light the need for innovation as a pre-condition for the survival of manufacturing companies. Therefore, there is a growing need for manufacturers to undertake innovation and maintain appropriate strategies. Innovation is an ongoing process, and its purpose is to achieve better performance while maintaining competitiveness (Davison & Hyland, 2006). The most common innovation types to achieve these goals are product innovation and process innovation.

Product innovation is the creation and subsequent introduction of services or products that are either new or a substantially improved version of previous goods or services. Implementing new or significantly improved production or delivery methods is process innovation. Process innovation is a major part of the product's life cycle and includes major changes in technology, machinery, and information systems. With the goal of cost reduction and improvement of product quality, amongst others, process innovation can be described as new foundations introduced into a company's service or production operations (Utterback & Abernathy, 1975, Rosenberg, 1982; Damanpour, 1991; Utterback, 1994). This research focus is on process innovation.

There are three main stages to providing process innovation: pre-implementation, implementation, and post-implementation (Kwahk & Lee, 2008). This research focuses on the pre-implementation stage, principally on the deployment of process innovation initiatives and the readiness to implement such initiatives in manufacturing. Organisational readiness to deploy innovation is an important issue in the pre-implementation phase (Kwahk & Lee, 2008). A methodological approach to prepare for the implementation of innovation activities can be facilitated by placing the concept of deployment readiness in the pre-implementation phase.

2.2 Concept of Innovation

In recent times, there has been a renewed focus on the importance of manufacturing to the growth of major economies in the world. Multiple studies have highlighted the need to support such economic growth with the development and maintenance of manufacturing capabilities as job opportunities, workforce, and security. Amongst these, perhaps the most important of them is the ability to innovate (Gachanja, Nga'nga' & Kiganane, 2020).

Framing a precise definition of innovation is fundamentally difficult, as the concept itself is often context-dependent, particularly in the field of science (Amidon, 2003). The following definition was adopted in this study; Frascati Manuel (OECD, 1981) noted that to successfully develop and market new or improved manufactured products, innovation necessary steps must be considered. Innovation encompasses the technical and scientific, as well as the commercial and financial. Examples may include the introduction of a new approach to the management of social services or the use of new or improved processes and equipment commercially. Innovation can also be considered a value-added process to an invention that improves its usability in the market. There are usually four dimensions to innovation: product, service, process and organisational innovation. Product innovation is defined as a new and/or advanced product, equipment and service (Knight, 1967; Cooper, 1998; Damanpour,1991). It can also refer to the first commercial use of a new product in the market.

This study focuses on process innovation. Process innovation involves the adoption of new and/or advanced manufacturing or distribution processes (Knight, 1967; Abernathy & Utterback, 1978; Cooper, 1998). It can also refer to the process of implementing new methods in the company, and while not necessarily unique to the market, such innovation will invariably change the company's production process (Palcic, Koren & Buchmeister, 2015). According to Neely and Hii (1998), product innovation and process innovation are said to be inseparable because of the nature of their dependent overlap; The innovation of a process leads to product innovation; contrariwise, innovation of a product may induce a process innovation. Aside from process and product innovation, there are organisational innovations that deal effectively with human resources and the development of a company. This type of innovation is both vital and beneficial for the creation and implementation of new ideas. As introduced in

Section One, this study focuses on process innovation in the manufacturing environment.

Innovation can be radical or incremental. ‘Radical innovations’, according to Green et al. (1995), are novel, revolutionary, pioneering, fundamental and significant. ‘Incremental innovations’, on the other hand, are small, gradual improvements that extend an already established process, product and/or service. The invention and introduction of the CD player is a clear example of radical innovation, and the replacement of a 16-bit chip with a 32-bit chip is an example of incremental innovation (Dewar & Dutton 1986; Norman & Verganti, 2014).

Some studies refer to innovation as “any new thinking, practice or material artefact by being quickly adopted in the environment which is relevant " (Biemans, 1992) or as “the adaptation of new and different notions and objects appropriate to a development of the product to a particular marketplace” (Rhodes & Wield, 1994). Additionally, further clarification and explanation has been introduced wherever the definition of innovation is “a phenomenon which contains both advanced technologies and more effective methods of performing things” (Tien, 1998).

There is an overwhelming consensus that companies need to innovate (Hamel & Prahalad 1998; Tidd & Bessant 2005; Mulgan & Albury, 2003), and the relationship between company management and innovation has been widely researched. Whether the company competes for a share of the market, simply seeks competitive advantage (Cooper, 2005; Hamel & Prahalad, 1998; Kaplan & Norton, 1992), or needs to advance its products or services (Hartley 2005; Mulgan & Albury, 2003) the necessity for innovation remains a ubiquitous constant (Tidd & Bessant, 2005). As Cooper (2005a, p.4) summarises: “its war: Innovate or die”.

Management of Innovation has been a subject of much scientific and management research literature, and an understanding of its importance is critical to the survival of any manufacturing company. Hansen and Birkinshaw (2007) suggested that a benchmark for the management of innovation can be found in an efficient, active and intelligent organisation that controls and implements actions which lead to innovation. According to Jacobs and Snijders (2008), the management of the innovation procedure extends not only to the management of developing projects to completion, but also to the management of their subsequent implementation, since, without the latter, no value is created.

Innovation is neither simple nor straightforward. In a situation where a company initiates an innovation process without following the necessary and appropriate steps, it will likely fail. For leading businesses (at the head of marketplace) innovation may be right and necessary. However, even these companies cannot realise 100% achievement even after with managing new changes and variations. (Hamel & Prahalad, 1994; Utterback, 1994; Christensen, 1998). It is stressed that the assessment of improvement and innovation capability (capacity) as a significant reason for such organisational failures is found in the absence of flexibility to adapt to the surroundings and environment, such as changes in user/client/customer demand and regulatory requirements. Once organisations become involved in innovation with their main experiences and competencies, they can become stuck or trapped without proper assessment of improvement and innovation capability (capacity) (Leonard-Barton 1992; Benner & Tushman, 2000).

In the first instance, the process of innovation needs to be examined in the detail of its component parts to understand where improvements can be applied. A successful company can achieve this process with the addition of a practical study design (Van de Ven & Poole, 1990; Rothwell et al. ,1974; Andrew et al., 2007). The process of innovation can help manage the efficiency of the design method and alter the components and factors that can lead to a significant decrease in the quantity of time needed and thus avoid delays. Furthermore, this process cannot be realised without evaluating innovation readiness (capacity) (Qi et al., 2020).

In the past three decades, research in innovation has offered various process models (Evitt, 2007). To evaluate innovation readiness, a thorough understanding of how to model innovation capacity theoretically and conceptually is needed (Rogers, 1962; Cooper, 1986; Rothwell, 1994). Currently, a limited number of models and frameworks have been highlighted in management literature, scientific manuals, and policy-related papers. Innovation can be ambiguously interpreted as an innovative but flexible set of designs (for service or product development) by improved features, improved manufacture, and exceptional aesthetics to realise the needs of current or upcoming markets and to deliver cost-effective benefits. This insight may be described as a specific (single) innovation, but it may lack the sustainability factor. (Sanni, 2018).

There is general agreement that innovation capacity (readiness) refers to a company's classification and structure in terms of its ability to move towards adapting product development and consolidating product markets (Biemans, 1992; Forsgren & Johanson, 1992; Alter Nohria & Ghoshal, 1997). Additionally, Drucker (1994) delivers a comprehensive examination of sources to pursue “innovation which is purposeful”, as businesses start their processes of innovation by employing resources which are internal, while Whitley (1998) focuses on management schemes and systems that affect the ability of the firm to perform various activities. Given the significance of innovation in the recent global economic environment and the volume of required investment, as well as the need for a stable return on investment (ROI), it is evident that without innovation, it is extremely challenging to gain a competitive advantage in any corporate and business segment (Muller et al., 2005).

2.3 Dimensions of Innovation

Over the last ten years, research in innovation (by scholars and practitioners) has led to a fundamental reconceptualization of its starting point. Innovation thus begins with a novel formulation of notion and thoughts, which are then utilised in the new development, or enhancement of a current process or product (Wolfe, 1994; Cooper, 1999; Amidon, 2003). Furthermore, innovation is proposed as a design theory or idea which combines any existing techniques and expertise to present an approach for a brand-new concept. (Sundbo, 1998; Bright, 1964). Cooper (1998) argued that innovation is characterised by multiple elements and multidimensional processes, many of which are dualistic: radical and incremental, continuous and technological/administrative, product and process.

2.3.1 Radical, Incremental and continuous

Green et al. (1995) suggested that incremental and radical innovations represent different dimensions of innovation. According to these views, Katila (2002) creates a notion that such disagreements do not communicate everyday reality in any way. This is for the rapid and radical changes characterised by innovation which leads to an argument that inspires incremental and radical innovation for coexistence. A performance scale is used to validate this reasoning, which indicates any growth or decline in the capacity to perform a specific purpose. In differentiating among innovation dimensions and any present substitutes, some would depend on a technique identified as "performance radicalness" (Knight, 1967). In other words, these dimensions determine the amount of change in an output taken from one innovation and compared with another (Knight, 1967). The concept of 'Continuous innovation' has been defined variously by researchers without uniform consensus (Teece & Pisano, 1994; Teece et al., 1997; Boer, 2002; Soosay, 2005; Davison & Hyland, 2006). Nevertheless, the ideas of "timely responsiveness and rapid product innovation" are common denominators in most definitions (Teece & Pisano, 1994).

This is adjunctive to the competence of management to both coordinate and make use of internal and external competencies. Therefore, in general, one can infer that to achieve continuous innovation in a company, the ongoing application of fresh knowledge and methods to actual improvements are essential. This applies to all company activities, including products, functions, facilities, and technologies. These will also encompass a logical, programmed, radical, or incremental method in the entire company that would include personnel from all departments (Soosay, 2005). In summary, to achieve better performance whilst retaining competitiveness, firms need to innovate their process continuously.

Continuous innovation also necessitates the application of individual and team learning and improvement teams, suggesting that the opinions of all stakeholders matter; ideas must be listened to, and concerns addressed. It further suggested that it is possible to acquire, earn and consolidate new knowledge and apply this when needed within the organisation (Boer et al., 2001). When companies are looking to innovate continuously, there will be interactional development in the fields of operations, gradual improvement, learning and radical innovation with the aim of effectively bringing together "operational effectiveness and strategic flexibility, exploitation and exploration" (Boer, 2002). To these ends, Coughlan (2000) suggests that continuous innovation creates a novel mix of "product-market-technology-organisation" that is new to everyone, including organisations, markets, societies as well as individuals.

Continuous innovation requires constant monitoring of regulatory policies, technologies, and the ability to achieve the changes it seeks to accomplish (Teece et al., 1997). This is essential for any company that wants to remain in business in a dynamic and unstable environment. Continuous innovation processes have evolved from other models of innovation processes, and these have been discussed in Section 2.4. The differences between innovation and continuous improvements are highlighted in

Section 2.6. Of the few published process models for continuous innovation, three of these models are the dynamic innovation model (Shang et al., 2010), the networking process model of continuous innovation and the networking approach (Xu et al., 2010). These models are described as follows.

Changes in new markets, advances in technology, people, and developments in society require companies to find the right formula for the right technologies, people, processes, and organisational cultures that permit them to become continuously innovative (Bessant & Boer 2002; Davison & Hyland, 2006). In the dynamic innovation model, Boer (2002) expresses continuous innovation as a continuous relationship that exists between elements such as operations, gradual progress, knowledge gained, and radical innovation (Figure 1). This facilitates the synthesis of exploitation and exploration, operational effectiveness, and strategic flexibility (Davison & Hyland, 2006). The dynamic innovation model (Shang, et al., 2010), shown in Figure 1, builds on the underlying logic behind the stability of innovation and the concepts of free enterprise, resource management, and dynamic capabilities. The model demonstrates the recurring connection between multiple capabilities for continuous innovation (Davison & Hyland, 2006).

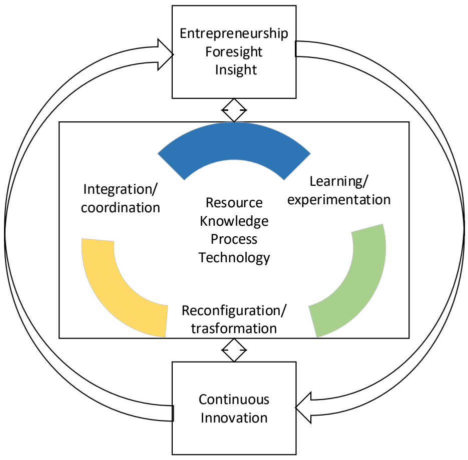

Figure 1: Dynamic innovation model (Davison & Hyland, 2006)

The dynamic innovation model requires authentic leadership as well as an entrepreneurial spirit with a desire to build solid capabilities for continuous innovation. It necessitates common sense to allow managers to make the best use of internal resources and seize opportunities when they arise. In addition, it requires organisations to set up iterative procedures to integrate new information and reconfigure vital resources.

In the networking approach (Xu et al., 2010), shown in Figure 2, knowledge management processes and systems are intricately linked to the capabilities of companies to perform continuous innovation. The premise is that continuous innovation requires a sophisticated 'networking process', with unique communication channels that allow for the flow of intensive feedback that will flow back and forth between products and processes. It thus requires excellent reporting within such a dynamic environment (Xu et al., 2010). As shown in figure 2, there are four basic but common phases within the innovation process: idea generation, research and development, prototyping and manufacturing, and marketing, sales and diffusion. Nevertheless, activities preceding these are rarely discussed and yet crucial for continuous innovation to succeed. The 'internalisation' is then added to the whole networking process from a perspective of the lifecycle (Xu et al., 2010).

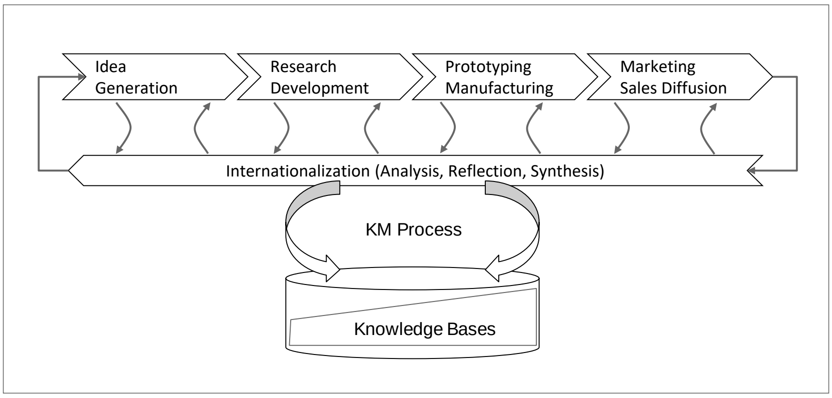

Figure 2: Networking process of continuous innovation

The two phases (common and internalisation) interact and communicate through a Knowledge Management (KM) process, which comprises part of the knowledge base. The common phases keep any existing channels open, whilst the internalisation phase in parallel with the common phases provides an important channel for incorporating the KM process into innovation (Xu et al., 2010).

2.3.2 Product and Process Innovation

Product innovation provides a variety of choices such as change (Cooper, 1998) and freshness (Damanpour, 1991) for companies as it meets the requirement of a client or marketplace, exemplified by the launch a new product that the company produces, sells, or donates (Knight, 1967). On the other hand, 'Process innovation' implies brand new, unique and special elements integrated into the firm's production processes. These are formed by alterations in the means in which a firm's goods are improved (Knight, 1967; Abernathy & Utterback, 1978; Cooper, 1998). Instances of such adjustments and changes can certainly be found in resources utilized, specifications of the task, methods for job, work and data flow, and the tools employed to manufacture a result (products) or raise the service quality (Knight, 1967; Abernathy & Utterback, 1978). Process innovation, product innovation, and a combination of the two are important dimensions of innovation in manufacturing. In summary, Product innovation entails creating and introducing goods and services that are either new or offer a substantial improvement to previous versions/iterations. Process innovation is the implementation of a new or significantly improved production or delivery method, including significant changes in techniques, machines and/or application software. Process innovation has been compared with product innovation, and the relationship between them are well documented. As in product innovation, implementation methodology and acceptance are central to the successful delivery of both these types of innovation initiatives.

2.3.3 Administrative and Technological

Regarding Evan (1966), as social business structures and technology have evolved, so have the accompanying administrative and technological innovation, which are uniquely different from the aforementioned types. Innovation which is technological refers to the fundamental production procedures and the routine job actions that maximally impact the development of brand-new concepts, which in turn are associated with such innovation (Knight, 1967; Damanpour, 1991). The volume of innovation applications which are technological in the areas of both process and products, such as information and communication technology (ICT), and the concomitant structural adjustments and changes help to define the characteristics of the production procedure (Damanpour, 1991).

Numerous studies confirm that the mixture of organisational innovation and technology is able to significantly enhance the results of innovation (De Toni et al., 1992; Scott, 2000). For instance, these adjustments and changes may impact the resources allocation, policies and other elements linked with the structure of the organisation, which invariably relates to Organisational innovations techniques (Cooper, 1998). As a result, numerous attempts and methods are affected, for instance: ‘total quality management' (TQM), 'just in time' (JIT), 'total process maintenance' (TPM), 'empowerment', and 'teamwork', (Schomberger, 1986; Flynn et al., 1996).

2.4 Model of the Innovation process

According to Papinniemi (1999), it is in how we design innovation that we can realize its significance as a method. This insight has improved over the years in that previous styles describe innovation as a direct arrangement of functional tasks. These models referred to obvious and tacit mental styles of management (Berkhout et al., 2006). This method combined finally with either: Technology Push (TP) – research which realises improvements to applications, which in the final instance create their method to reach the market, or (NP) Need Pull – requirements of the marketplace for novel things that lead to novel results and achieve the desired aims. These techniques are not without their challenges, since functional innovation is a method through which dealings are of supreme significance and which involves the relationship of various methods altogether (Berkhout et al., 2006; Rothwell, 1994). In most circumstances, a 'Pull' is potentially a more powerful system and entity than a 'Push', but innovation which is effective, however, still requires needs cooperation between the two. It is essential to control and manage innovation by defining a perception of ambiguity, difficulty, and a set of risky situations. More recent findings have identified that specific linear methods have their own set of limitations and as such, recommend greater collaboration and linkages to the bases and structures. Throughout the process of innovation, numerous elements tend to cause disruption within its life cycle. Projects may face a false start, have limited or no communication during the process, or incorporate poorly designed sequences, each of which has the potential to end in a failure of the process as a whole (Papinniemi, 1999). Van de Ven et al. (2000) conducted a study on the drawbacks of simplistic innovation procedure patterns aiming at the complicated techniques in which innovations progressed during the time and enhanced some significant differences and changes.

Shocks may lead to improvements in innovation! When companies or stakeholders are disappointed, adjustment is unavoidable once a window of chance is free and open. Even with a common starting point, development of theories, ideas and procedures improve in various ways,. Obstacles arise, schemes are over-assessed, mistakes proliferate, ill-conceived phases improve, and responsibilities increase because of external impacts; innovation is reformed, unforeseen occurrences appear, and there might be modifications to the involved people. Senior management may be engaged in the whole process from different angles while attempting to provide analytical support in the face of criticism. As a result, the process of innovation may become political and diplomatic and the likelihood of success dependent on a range of variables, such as the particular teams engaged at any given time. Because innovation seeks improvement, events occur that can assist with the understanding of procedure, but the resultant evidence, in turn, may lead to cynicism and distrust.

Roy Rothwell (1994), in his paper titled “Towards the Fifth-generation Innovation Process”, recommended that the perception of the process of Innovation in its extremely nature was advanced from uncertain lined replicas (characteristic of the 1960s) concerning methods of communication that are incrementally complex. The concept of 5th generation innovation was described by Suziyana et al. (2011) as a “multi-actor” method involving consolidation at both inter-company and intra levels, and which was driven by the integration of technology. Also, it was argued that foremost adjustments in the marketplace, caused by industrial and economic and environmental constraints, were responsible for the growth of recent generation patterns. During this period, this is how industrial firms formed and structured their processes of innovation by utilizing the five groups of an innovation pattern outlined by Rothwell. With the application of technological innovation at international and high-tech firms, he recognised that he could use his styles while designing a broad industry innovation management strategy (Sun et al., 2012). As previously stated, the linear models of “Technology Push” and “Market Pull” , are the two main methods used to observe the process of innovation. Both methods refer to either the sources of innovation, companies who innovate, or the motivations for innovation (Lubik et al., 2012).

2.4.1 Technology Push (TP) – First Generation (1G)

In recent times, companies have opted for a ‘need pull’ strategy as a result of ‘market share wars’, that is to say, a serious struggle and competition in the marketplace. Shareholders began to emphasise primarily a ‘rationalisation of technological change’ as a replacement for brand-new manufactured goods and associated expansionary change, which is technological (see, e.g. Mensch et al., 1980). Reacting and responding to client demands became the primary emphasis. Analyses of cost-benefit were set in place for all study plans and projects, which involved organized delivery and distribution, and resources management. This encouraged improved collaboration between the various departments, eg operating units and R&D. This was attained by decreasing 'time-to-market' distribution by combining members of research teams with product engineers (Miller & Morris, 1999). This had commonalities with the similar previous linear view of "Market Pull" with its emphasis on the marketplace, given that the market is considered the key source of notions and ideas that guide research, and that development should be reactionary to this. To put it another way, it substituted the approach of the first-generation supply-side along with the 'demand-side element' (Rothwell, 1992). The main disadvantage of the (2G) Second Generation model is that much emphasis is geared towards enhancements based on the market of the existing product, which in turn leads to various projects which are smaller (Miller & Morris, 1999).

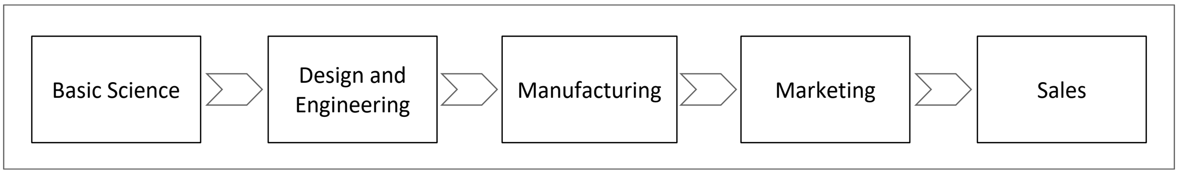

Figure 3: First Generation (Rothwell ,1994)

2.4.2 Market Pull (MP) – Second Generation (2G)

In recent times, companies have opted for a 'need pull' strategy as a result of serious struggle and competition in the marketplace, causing a 'market share war'. Shareholders began to emphasise primarily 'rationalisation technological change' as a replacement for brand new manufactured goods and associated expansionary change, which is technological (see, e.g. Mensch et al., 1980). Reacting and responding to client demands became the primary emphasis. Analyses of cost-benefit have been set in place for all study plans and projects, which involved organized delivery and distribution and resources management. This encouraged improved collaboration between the various departments, e.g. operating units and R&D. This was attained by decreasing 'time to market' distribution by combining members of research teams with product engineers (Miller & Morris, 1999). This was, in a way, the similar previous linear view of "Market Pull" with highlighting the marketplace. Given that the market is considered the key source of notions and ideas that guide research and development and is supposed to react to it. To put it another way, substituting the approach of supply-side of the model of First-Generation along with the 'demand-side element (Rothwell, 1992). The model of Second Generation (2G) has the main disadvantage in that much emphasis is geared towards an enhancement commenced by the existing product's market, which in turn leads to various projects which are smaller (Miller & Morris, 1999).

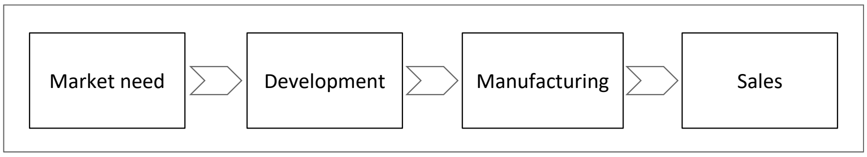

Figure 4:Second generation (Rothwell ,1994)

2.4.3 Coupling of R&D and marketing – Third Generation (3G)

Western economies faced significant economic shocks in the 1970s with accompanying economic downturns and consequently businesses were obliged to justify the reasons for concentrating on industry strengthening and the development of manufactured goods sets and portfolios. R&D projects were rejected, and any remaining projects were aligned to marketing departments utilizing configuration and structure processes of innovation. A reduction in operating process costs was the main reason for the development and modelling of these connections (Miller & Morris, 1999). However, it is knowledge, technology and the relationships with marketplaces which are the motives and reasons underpinning innovations of technology. Now, it is neither technological pressure nor market pull alone which are the drivers of revolution and innovation.

Arguably, there ought to be a hybrid mixture of the two. The procedure stays linear but with the capability for hindsight if required. Marketing and R&D attempt to stabilize and balance the formulation, highlighting the relations which link among them all together (Rothwell, 1994). These are open R&D types that are realized as (3G) third-generation versions (Berkhout, 2006). Thus, in contrast to providing solutions to societal requirements and organisational barriers, 3G focuses on brand-new technology abilities in a business. It is similar to an emphasis on process and innovation (technical) while disregarding the innovations of business and marketplace (non-technical).

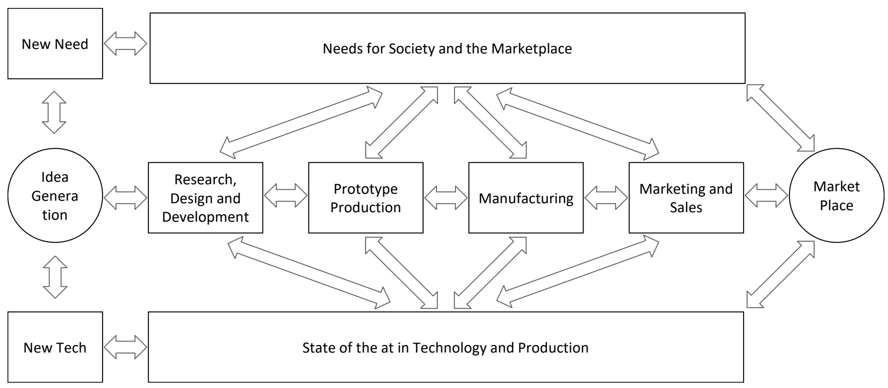

Figure 5: Third Generation (Rothwell ,1994)

2.4.4 Integrated business processes – Fourth Generation (4G)

Following the recovery of the economy in the 1980s, it was feasible to reduce the innovation life cycle of manufactured goods. The emphasis was placed on integrated products and processes for improving a 'total concept' (Rothwell, 1994). The subsequent moving from point to point (function-to-function) was eliminated, switching to a process of actual development, which is parallel. Moreover, the business itself was incorporated into the entire process of innovation, alongside strategic providers and customers (end-users) (Berkhout, 2006). Additional focus was put on the communication mode, including the untidiness and non-linearity of the process of innovation itself. Although the innovation itself continues to be cross-functional, R&D develops different tasks the process of innovation. The (4G) Fourth Generation version, then, aims at a multiple and parallel understanding between both customers and suppliers equally.

Example of the 4G model from (1987):

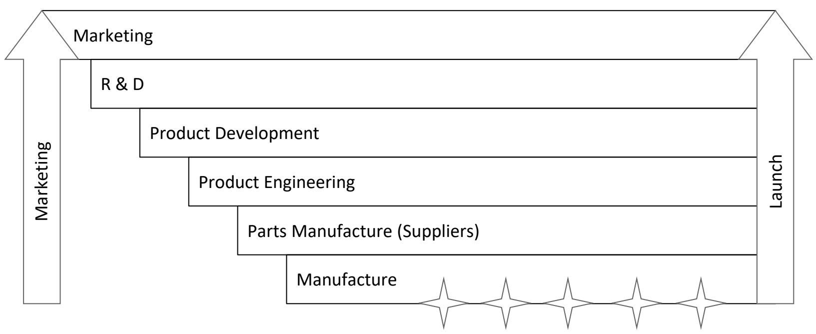

Figure 6: Fourth Generation (Rothwell ,1994)

Figure 6 illustrates the internal features of the Fourth Generation. These are integrated and parallel features of the 4G procedure, which build upon the network of external communications shown in the Third-generation process (see 3G model).

2.4.5 System integration and networking – Fifth Generation (5G)

The early 2000s were characterised by budget shortfalls and recessions which led to economic downturns, and this brought about huge pressure and constraints on resources at all organisational levels. The thinking for most organisations at this time was to look for ways that would mitigate such problems in the future, and this led to the introduction of Information technology, networking, and system integration as well as corporate procedure automation through Manufacturing Information Systems (MIS) and Enterprise Resource Planning (ERP). Additionally, strategic partnerships were formed using collective marketing and open innovation (Berkhout, 2006). The (5G) Fifth Generation process was in many ways similar to the previously discussed processes of networking.

Another valuable element in 5G is the 'time/cost trade-off' as a "quick innovator" can define a company's competitiveness. This is particularly true in environments where technology is changing rapidly, and the life cycle of a product is getting shorter, noting that shortening the innovation cycle raises progress costs (Rothwell, 1994).

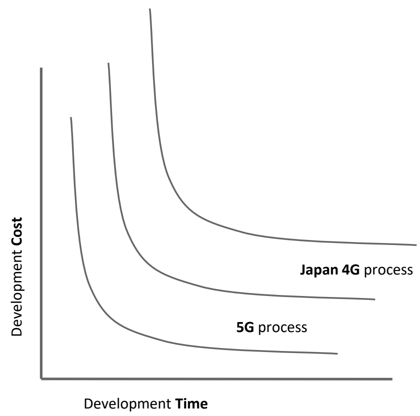

Figure 7: Product Development for 3G, 4G and 5G Innovation Processes (Rothwell ,1994)

In the 5G model, the focus is on the delivery of a vertical connection between providers and suppliers along with clients through the process of innovation. For instance, when these stakeholders are participants in relation to the expansion procedure of any following goods and/or applied distribution of knowledge and technology, a number of connections may happen. Examples include collaborations, joint ventures, alliances, and consortia, (Miller & Morris, 1999). The features of the 5G have already been integrated by pioneers and innovators that have understood the process of 4G such as "flatter structures, parallel and integrated operations, involvement with leading customers and horizontal alliances, early and effective supplier linkages"

Rothwell (1994). The use of cutting-edge technologies is an essential feature of 5G, making the operation more efficient. However, in recent decades, there have been numerous significant facets of innovations which are industrial, for example electronic measuring and analytical equipment, and computing devices. 5G has developed an extensive and full procedure of “innovation automation” throughout the entire system of innovation (Miller & Morris, 1999). The two most recent generations (4G & 5G), in contrast with preceding generations which focussed on successive technological innovations, emphasize “multi-actor” characters and cross-functionality. .

2.5 Diffusion of innovation

The OED (2020) defines diffusion as ‘the state of being spread out or transmitted’. In the manufacturing literature, Rogers (2003) defines diffusion as ‘a process whereby innovative information is shared through certain channels over time among the members of a social system’. Diffusion of innovation (DOI) theory edifies the process by which innovations, novel or new ideas, are shared across and within organisations (Lundblad, 2003). Diffusion of innovation can be defined as the adoption and implementation of new ideas, products or services (Amar & Davis, 2015). DOI theory describes the relationship of how the adoption of innovation is formed by organisational/individual decision-making processes, the mode and channels used for communication, the characteristics of the innovation being considered, and the potential risk that may be involved (Rogers, 2003; Song, 2014). Despite a shared interest in the DOI theory among researchers and practitioners alike, there is evidence that innovations often are not diffused within and across organisations (Zanello et al., 2016). For instance, there are a few scenarios in which the relevance and importance of DOI has been illustrated from both theoretical and practice perspectives. In manufacturing, new ideas are continuously developed in research and practice settings, yet these innovations often take time.

Rogers (2003) describes the attributes that conceptualise the factors that influence the spread of innovation and influence the decisions of potential innovation adopters in his pioneering book Diffusion of Innovation. According to Rogers, diffusion is related to two key factors: the need to be correct in the context in which innovation is disseminated and the fact that a vector for the dissemination of communication for the purpose of information transfer must be introduced.

2.5.1 Innovation-diffusion view of ERP implementation

Enterprise Resource Planning (ERP) systems are essential to gaining and maintaining a competitive advantage in ever-increasing global markets. ERP systems integration supports core business processes such as accounting, finance, manufacturing and human resource management by providing a unified platform mediated by technology and software applications (Chang, 2006; Shang & Seddon, 2007; Han & Ahn, 2013). While critical effectiveness is reported through ERP, there are cases of failed implementations and unsatisfactory performance. Diffusion of Innovation (DOI) theory and Information Systems (IS) Success theory (Delone & McLean, 1992; Rogers, 1983; Fichman, 2000; Rajagopal, 2002; Bradford & Florin, 2003) have been used by researchers to develop models of ERP successful implementation.

Diffusion is a process of providing innovation through a certain channel between members of a social system (Rogers, 2003). This process involves a combination of five phases, comprising a two-phase initiation sub-process and a three-phase implementation sub-process (Lundblad, 2003). DOI theory asserts that the diffusion and success of IT initiatives can be significantly influenced by the characteristics of the organisation's innovation and its environment (Fichman, 2000; Rogers, 1983). Nevertheless, the diffusion process of innovations is complex (Bradford & Florin, 2003), and the important dimensions of innovation that will influence successful ERP implementations are also reported to include technical compatibility, technical complexity, and business process reengineering (Tornatzky & Klein, 1982; Davenport, 1998; Fichman, 2000; O'Leary, 2000). Many companies conduct process innovation in tandem with ERP implementation (Willcocks & Sykes, 2000; Law & Ngai, 2007), and there is a consensus that process innovation needs to be continuous for the organisation to successful accrue the benefits of ERP (Kettinger & Grover 1995; McGinnis & Huang, 2007). There is a growing number of examples of simultaneous implementation of ERP and process innovation initiatives. These include concurrent implementation of ERP and knowledge management (Newell et al., 2003; Acar et al., 2017), integration of ERP and business intelligence (Nofal, 2013) and joint implementation of ERP and business process re-engineering (Pattanayak & Roy, 2015).

Joint implementation of business process re-engineering (BPR) and ERP are quite common because ERP packages are usually built around best practices (O'Leary, 2000), and the software does not necessarily conform to the operating practices of the adopting organisation. As a result, the adopting organisation may either need to customise the package to fit its operating practices or to re-engineer its business processes to conform to the package (Jenson & Johnson, 1999). BPR involves a radical redesign of the process to significantly improve costs, quality and service (Hammer & Champy, 1993). If complementarities between BPR and ERP are possible and if BRP and ERP can be achieved, it can be successfully implemented in tandem with excellent results. BPR, BI and ERP can all gain synergies that enable the powerful and efficient integration of two functions, namely the analytical capabilities of BI systems and the data management capabilities of ERP systems. Many new enterprise information systems are reported to fail due to implementation failure rather than innovation failure (Klein et al., 2001).

There are several factors influencing ERP implementation and effectiveness; these include organisational factors, the climate of implementation, project management skills, change management orientation, and stakeholder considerations, including the supply chain (Stefanou 1999; Klein et al., 2001; Umble et al., 2003; Kemp & Low, 2008). There are several recommended methodologies for ERP implementation. Kwon and Zmud (1993) proposed six stages consisting of initiation, adoption, adaptation, acceptance, routinisation and infusion. Rogers (1983), in his innovation diffusion theory, suggested five stages comprising conditions for adoption, knowledge about innovation or technology, persuading possible adopters through deepening of the knowledge about technology and research, a decision to adopt or reject the technology, implementation, and confirmation involving acceptance or rejection of the technology.

The use of technology during the ERP implementation phase is significant. Its implementation comprises three phases: pre-implementation, implementation, and post-implementation. The pre-implementation stage is essential for successful implementation, and it involves planning and organising activities in readiness for deployment. A lack of planning for deployment at this stage will likely lead to failure. Organizations implement ERP systems and start using them during the implementation phase. The post-implementation stage is where knowledge transfer often takes place. The ERP system evolves through a process of continuous improvement. Javahernia and Sunmola (2016) exemplify this with a five-step process innovation deployment methodology that consists of a) setting out the objective of the deployment, b) developing a deployment plan, c) assessment of deployment readiness and conducting acceptance tests, d) exploring opportunities for improving the level of readiness, and e) improving readiness levels, if possible, otherwise deploy.

Whilst the rationales for simultaneously implementing ERP with process innovation initiatives are often clear, less so is the best approach to accomplish the implementation in tandem. For example, questions arise as to whether process innovation should come before ERP implementation or whether they both should be implemented with the same starting and finishing times. For example, regarding ERP and BPR, as questioned by Pattanayak & Roy (2015), should it be 'BPR and then ERP or ERP and then BPR?'. It has been suggested that since ERP systems often require examination of business processes, then ERP systems should pave the way for BPR (Kremmergard & Moller, 2000). In some organisations, an ERP system is used to promote BPR (Martin & Chang, 2000), and for some others an ERP system triggers BPR.

2.6 Innovation and Continuous improvement

According to Tushman and Nadler (1986), innovation receives a great deal of attention because it is perceived as a tool for growth and competitive advantage. The same can be said of 'continuous improvement' as it has advanced rapidly in the field of operations management. Businesses seldom ignore the benefits realised by continuous improvement as a core philosophy, especially in manufacturing (Dean & Bowen, 1994). Yet, the two approaches remain different, and there are experts that question whether the two approaches can exist hand-in-hand within the same organisation. Realistic success in both philosophies is not always possible, especially when companies have to choose between quality and innovation (Prajogo & Sohal, 2003). To these ends, several academics have tried to explain the variances and similarities between the two. Maguire & Hagen (1999) state that there exists incompatibility between innovation and continuous improvement because continuous improvement was created for quality management whilst innovation is needed for the introduction of new products and services. Madrigal (2012) summarised the main differences between innovation and continuous improvement in his research (See table 1).

Table 1:Differences between innovation and continuous Improvement adopted from Madrigal (2012)

Dimension	Innovation	Continues Improvement
Time frame	Continuous and incremental	Intermittent and non-incremental
Change	Abrupt and volatile	Slow and gradual
Scope of the effort	Technological breakthroughs, new innovations, new theories	Conventional know-how
Advantages	Works well in fast-growth economics	Works well in slow-growth economics
Requirements	Large investments	Low investment
Modality of work	Scrap, rebuild or replace	Maintenance and improvement

There is a consensus that the two approaches are naturally different, but a link exists between the two which necessitates consideration. McAdam, Armstrong and Kelly (1998), in evaluating the relationship between continuous improvement and innovation, using a sample of fifteen companies, showed some correlation and their conclusion indicates that there exists a causal relationship between the two philosophies whereby the introduction of continuous improvement can lead to incremental innovation.

In today's competitive and globalised markets, manufacturing firms are constantly on the lookout for novel ways to improve and eliminate waste in their processes while simultaneously implementing continuous improvement initiatives. Concepts like lean, total quality management (TQM), business process engineering (BPR) and six sigma are developed viewpoints that have been successfully implemented by manufacturing firms to enhance their business processes (Upton & Kim, 1998). These improvement philosophies focus on identifying, analysing, improving and sustaining the business processes (Sousa et al., 2019). Lean and Six Sigma are the most common process improvement methodologies and have been adopted by many organisations in the manufacturing, service, logistics and healthcare industries (Indrawati & Ridwansyah, 2015). A lean manufacturing process is an effective approach that primarily focuses on the reduction of waste in manufacturing processes. Such waste includes defects, waiting times, overproduction, excess inventories, inadequate processing and unnecessary transportation (Aqlan & Al-Fandi, 2018). With the reduction of waste in a process, the system becomes efficient and invariably leads to the reduction in the overall costs of the firm. The implementation of lean manufacturing can improve firm efficiency through the reduction of the setup time, inventory and unnecessary or excess motion, and by increasing process flexibility, visibility and the implementation of a push-pull system (Sutari, 2015).

Quality Circles and Six Sigma are examples of process improvement philosophies that can contribute to innovation in a manufacturing company and drive organisational innovation by improving process efficiency and quality.

Six Sigma was introduced by Motorola in the 1980s and was based on the reduction of variation in the processes. This philosophy aimed to reduce manufacturing defects to the lowest possible level (3.4 defects per million opportunities) (Gleeson et al., 2019). To eliminate such defects, this methodology seeks to identify the causes of defects and develop an effective and efficient corrective set of actions through a set of procedures known as "Define, Measure, Analyse, Improve, and Control (DMAIC) (Pereira et al., 2019). Six Sigma is used in the manufacturing and service sectors to reduce defects, improve quality, reduce delivery times, improve business profitability and customer satisfaction, and reduce costs (Patel & Desai, 2018); these free resources can be used for innovation and new product development.

At the start of the 1980s, Quality circles (QCs) were adopted as an innovation to renovate companies, mainly in Europe and America. With a focus on improving quality and productivity, groups of employees come together to build an approach to problem prevention by recognising and solving any problems at work. The main objectives are to involve employees in the improvement process by providing employee empowerment for the quality of their work (Hill, 1991). This could lead to finding innovative explanations for problems and encouraging a culture of continuous improvement (Goldstein 1985).

Quality Circles have been used in different services and industries. For example, QCs have been used in health care to innovate, improve quality, or provide services more safely, efficiently, and, more importantly, with less waste (Tetteh, 2012), or in the manufacturing environment QCs have been used to find the root of problems and identify solutions which improved the overall quality of the product. QCs team collect data, observes, and gathers feedback from employees. They try to identify the root of the problem which caused the defect. They can then recommend solutions, such as modifying the process or training employees (Romero, Gaiardelli, Powell, Wuest, & Thürer, 2019).

According to Möldner, Garza-Reyes and Kumar (2018), Process innovation (PI) is essential for manufacturing firms, and that organisations cannot afford to disregard the importance of innovation. Its importance has been widely acknowledged in theory but in practice little has been done. To this end, both practitioners and scholars of innovation agree that openness at the firm level raises barriers and challenges in management that require specific skills and internal coordination (Chesbrough, 2006; Huston & Sakkab, 2006; Chiaroni et al., 2011; Lichtenthaler, 2011; Ferraris, Santoro & Bresciani, 2017).

Two main methods have been suggested within the process innovation paradigm (Huizingh, 2011; Santoro, Bresciani & Papa, 2018). The inbound method refers to the need for external knowledge and technologies from external organisations and individuals. In contrast, the outbound methods concern the transfer of knowledge and technologies to external organisations or individuals for companies. To benefit from inbound and knowledge acquisition activities, management must have the ability to align the knowledge acquisition process with the company's R&D activities (Noseleit & de Faria, 2013; Estrada et al., 2016; Santoro, Vrontis, Thrassou & Dezi, 2018). In addition, these innovation capabilities are based on innovation management practices and procedures at the tactical, strategic and operational levels (Ernst, 2002; Aziz & Rizkallah, 2015). These management capabilities ensure that knowledge is successfully organized, mobilized and applied to achieve organisational goals (Franco & Haase, 2017; Thrassou et al., 2018b).

The practice of managing process innovations within company boundaries thus supports the transfer of external knowledge (Cohen & Levinthal, 1990; Huizingh, 2011; Ferraris, Santoro & Dezi, 2017). These practices also complement a firm's ability to absorb external knowledge and represent a key capacity to align the company's ability to incorporate external knowledge transfer activities with the company's innovation (Todorova & Durisin, 2007). Companies are required to develop different skills for joint management of internal and external knowledge together, namely, research integrative, knowledge management and adsorptive capacities (Cohen & Levinthal, 1990; Zahra & George, 2002; Bogers & Lhuillery, 2011; Ahn et al., 2016).

2.7 Manufacturing process innovation

Manufacturing process innovation (MPI) can be defined in a variety of ways, including as 'an organization-wide effort that involves fundamental rethinking and radical redesign of manufacturing-related processes and systems to achieve dramatic improvements in manufacturing performance measures such as cost, quality, service, and speed' (Hammer & Champy, 1993). In MPI, innovation is not only limited to processes but can also include operations and all activities involved in the product transformation process ranging from raw-material acquisition to the supply of new products. Also covered are support systems such as production planning, logistics, purchasing, administration, engineering, and management.

Implementing computer-aided manufacturing (CAM) system is an example of process innovation in manufacturing. This has been used to improve quality control, reduce waste, and increase efficiency by automating the manufacturing process. Another example of using this type of process innovation is using robotic bending technology for sheet metal companies. Compared to traditional press brake methods, new technology helps companies to reduce their environmental impact by optimising the use of materials and reducing the amount of scrap metal produced, resulting in less material waste and more efficiency.

Central to implementing MPIs is ensuring an appropriate level of deployment readiness. The latter represents the extent to which deployment has run smoothly and is relatively problem-free (Ahmadi et al., 2015). In general, readiness implies a state of preparedness for something about to happen.

The benefits of deployment readiness in manufacturing include addressing potential risks at the early stages, particularly at pre-implementation, leading to better deployments that minimise unforeseen problems post-implementation. Extensive preparation before implementation is the key to the success of deploying innovation initiatives, and without proper readiness, the deployment is likely to end in failure (Ahmadi et al., 2015; Razmi et al., 2009). Essentially, having an assured deployment plan will help provide confidence in the degree of readiness to achieve the best possible deployment. This will require a method of measuring innovation deployment readiness and testing deployment plans. A number of methods of measuring innovation deployment readiness are available (Ahmadi et al., 2015; Razmi et al., 2009; Javahernia & Sunmola, 2017). Razmi et al. (2009) studied the interrelations between influential factors of deployment readiness using an analytical network process (ANP) and fuzzy cognitive maps (FCM). An approach to optimising deployment readiness in the context of ERP, subject to budget constraints, is explored by Ahmadi et al. (2015). They argue that in estimating the deployment readiness of an organisation, it needs to consider the interrelationships between finding the best improvement plan as a multi-objective trade-off and maximum readiness, cost and the important readiness factors. Finally, a sequential decision process framework for innovation deployment readiness assessment is proposed by Javahernia & Sunmola (2016).

2.8 Deployment readiness

Innovation deployment, as defined by Klein & Sorra (1996), refers to the process by which target employees are committed to the use of an innovation that can be rationalised whilst requiring both tweaking and commitment from business leaders. The implementation of innovation comprises three stages (pre-implementation, implementation, and post-implementation) and the readiness of an organisation to deploy innovation is an important issue in the pre-implementation phase (Kwahk and Lee, 2008). During the pre-implementation phase, the organisation prepares itself and develops the plans for deploying its innovation initiative. Extensive preparation prior to implementation is key to the success of deploying innovation activities, and deployment is likely to fail without adequate preparation (Ahmadi et al., 2015). The concept of deployment readiness in the pre-implementation phase allows for a more methodological approach to preparation for the implementation of innovation initiatives.

In a series of pioneering works, Jacobson (1957) first introduced the concept of readiness, which has since been developed by several others, including in engineering (Lim & Jiju, 2013). There are different definitions of readiness, such as organisational and technological readiness. Organisational readiness generally refers to 'the extent to which organisational members are psychologically and behaviourally prepared to implement organisational change' (Adams et al., 2000). High levels of organisational readiness are likely to result in efficient implementation of the proposed change due to the inclination of the organisational members to be collaborative, exhibiting greater effort and intelligence with the implementation of the planned change. On the other hand, low levels of organisational readiness present problems with members of the organisation likely to exhibit uncooperative behaviour and avoid or even resist actions that would lead to more effective implementation of the proposed change.

Parasuraman (2000) defined technology-readiness constructs as 'people's propensity to embrace and use new technologies for accomplishing goals in home life and work.' These highlighted constructs draw out the challenges in deploying innovation initiatives in manufacturing, principally the complexity and uncertainty associated with the target organisation, the manufacturing technology, and the processes. In retrospect, deployment readiness indicates the degree to which the deployment runs smoothly in a ready-to-deploy state and is relatively unproblematic (Ahmadi et al., 2015). It is a state of preparedness for something about to happen. The benefit of deployment readiness in manufacturing includes addressing potential risks in the early stages, which leads to better deployments that minimise unforeseen problems in production. There are some forms of deployment of innovation initiatives in manufacturing and depending on the degree of readiness.

Alireza and Sunmola (2017), in their study, focused on innovation activities in the context of manufacturing operations and processes, including, for example, Statistical Process Control (SPC) and Six Sigma, Enterprise Resource Planning (ERP) deployment (Ahmadi et al., 2015), and RFID integration into shop floor operations (Chuang & Shaw, 2008). Companies that are lacking in many key areas are said to be handicapped by low levels of innovation deployment readiness and thus lack the capability to create a successful platform for continuous innovation. As such, companies may not be able to realise the full benefit of their investment due to the low level of readiness to deploy innovation initiatives. Therefore, it is necessary to conduct an assessment in the early stages of implementing an innovative measure with the purpose of achieving the highest readiness degree and identifying weaknesses or problems which may lead to failure.

2.8.1 Models of deployment readiness

The deployment of innovation requires a series of steps, some of which are part of the preparation for deployment and vary from initiative to initiative. An attempt at generic methodologies for innovation deployment has been fruitful, although mostly in the field of Information Technology and Software Engineering. An example relates to the methodology offered by the Cisco unified communications system (Cisco, 2008); see Figure 8.

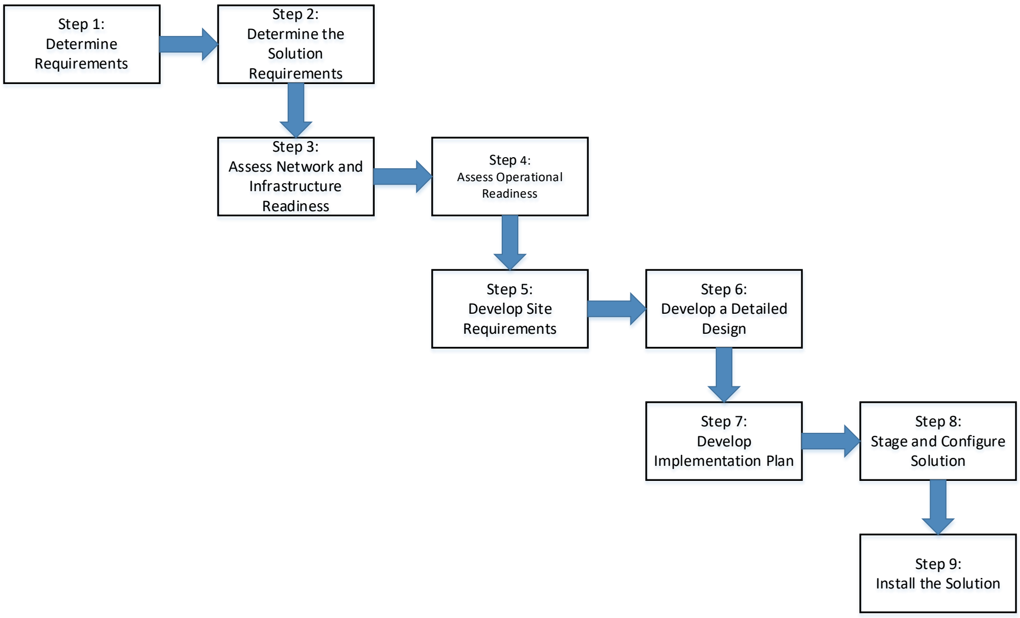

Figure 8: Deployment steps of a Cisco Unified Communications system, Adapted from Cisco (2008)

In Figure 8, deployment readiness is assessed early in the process, and this includes steps 3 and 4. Another interesting example of deployment methodology is that of the deployment of organisational project management methodology (Aziz, 2015), which is illustrated in Figure 9.

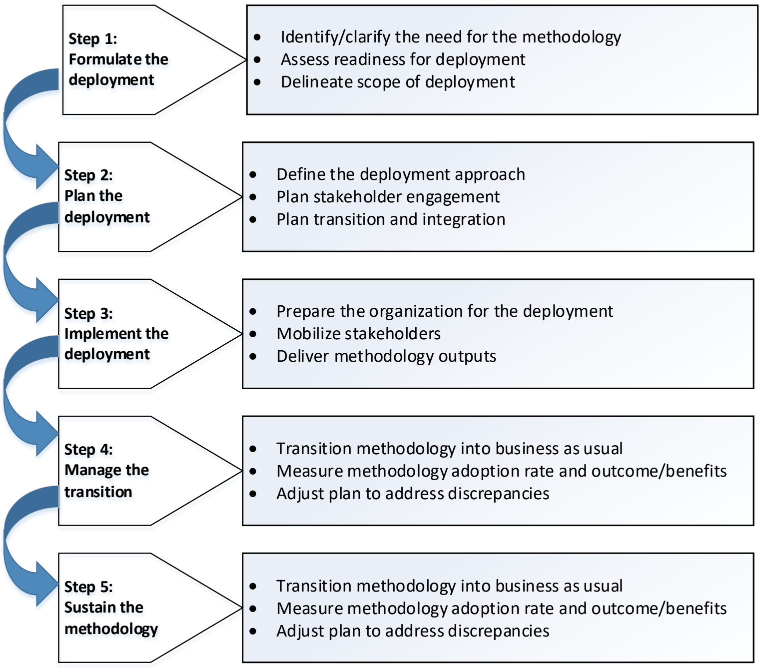

Figure 9: Deployment steps of organisational project management methodology, Adapted from Aziz (2015)

Several researchers have begun to seek ways to maintain the highest level of readiness. For example, regarding Enterprise Resource Planning (ERP), in recognition of budget constraints, Ahmadi et al. (2015) suggest that in order to estimate the deployment readiness, an organisation must consider the interrelationship between influential readiness factors in the organization and prepare an optimal improvement plan as a multi-objective trade-off between maximum readiness and cost. The methodological approach of Ahmadi et al. (2015) entails four main steps: a) construct a readiness assessment model, b) estimate the overall readiness degree of the organisation, c) analyse the readiness degree, and d) provide a set of efficient plans to improve the overall readiness degree of the organisation. Fundamentally, this approach raises two important issues. That is, how to measure the degree of readiness and how to optimize the degree of readiness to achieve the best deployment.

Very little research has been undertaken so far on the readiness to deploy innovation in manufacturing. In contrast, studies have focussed on related concepts, for example, innovation implementation readiness, and in particular, the effectiveness of ERP adoption (Maditinos et al., 2011). Research on the effects of implementation effectiveness in the wider literature, such as Klein et al. (2001), Sawang (2008), and Weiner (2009) (see Figures 10, 11 and 12, respectively), offer considerable insight into the variables that significantly predict innovation implementation effectiveness and the resulting conceptual framework.

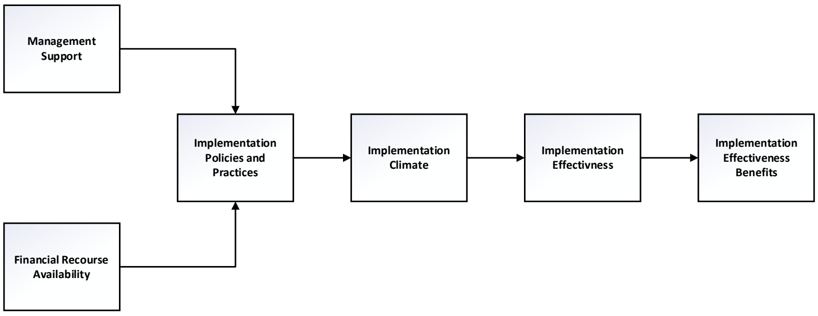

Figure 10: Implementing computerized technology: an organisational analysis Adapted from: Klein et al. (2001)

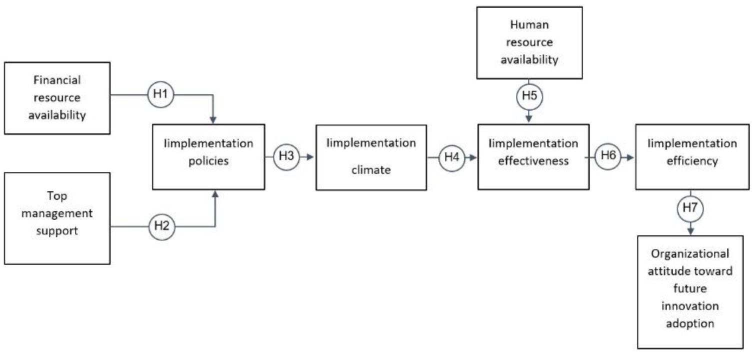

Figure 11: The extended model of implementation effectiveness Adapted from Sawang (2008)

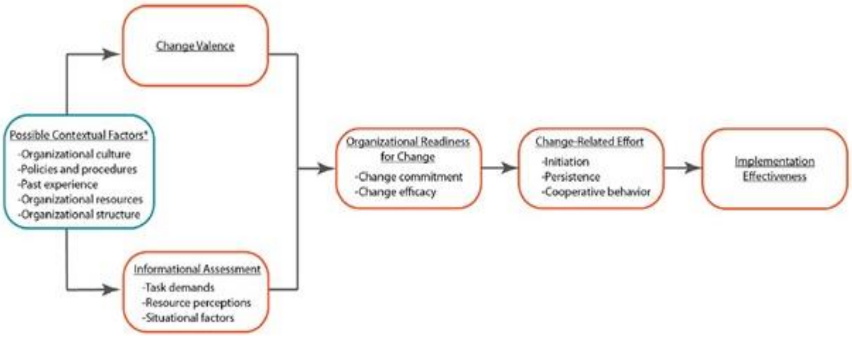

Figure 12: Determinants and outcomes of organisational readiness for change Adapted from Weiner (2009)

The framework presented in Figure 10 was developed by Klein et al. (2001), and it presents an implementation effectiveness model which is based on the premise that organisational differences in innovation effectiveness are related to implementation effectiveness, which in turn is related to the systematic support of implementation, availability of financial resources, policies and practices, and climate. This model enriches early innovation research and incorporates the theoretical importance that underlies the practical framework of early research (Weiner et al. 2007). The framework study shown in Figure 11 was presented by Sawang (2008) and was the first of its kind, taking into account personnel and organisational attitudes towards the adoption of innovation. Finally, the framework stated in Figure 12 is presented by Weiner (2009), and there are improvements in the first two frameworks (figures 10 & 11) when providing organisational determinants and results for change.

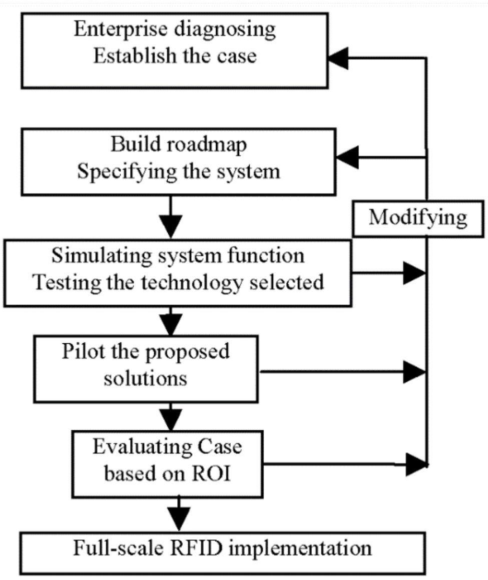

Figure 13: A five-step process to deploy RFID applications (RedPrairie, 2004)

Another example is the RFID implementation process (see figure 13). A process with five stages to organise applications of RFID designed by Red Prairie (2004), took into account, a process of a checking list to perform prior to applying RFID during implementation in manufacturing. This will start by identifying goals and targets, teaching and creating understanding, evaluating the corporate case, determining the knowledge and technology, testing, examining the findings before returning to investing, setting up the RFID system, and ultimately maintaining developing and evaluating the structure and system. Moreover, Moretti et al. (2019) highlight three problematic aspects which need to be taken into consideration prior to applying RFID in business: development challenges functioning difficulties, and problems related to members and the execution phase.

Ting et al. (2013) proposes a structure with six stages for the application of the RFID system, which is similar to the aforementioned methods in that it involves both scientific and technical aspects of humans. The standard duties in the first stage, scoping of the project, are assessing the possible benefits and constraints of systems of RFID and identifying the goals of the project. Performing this evaluation helps prevent unworkable opportunities for RFID implementation and provides a certain path of plan goals to the execution unit. Next, the present structure is examined, and different techniques are employed to collect data on the current form. This assessment helps the detection of required processes. Stage three, the design of the system, is dependent on the previous method of evaluation. The layout of the system ought to be ideally appropriate for the businesses' demands and requests. This step involves necessity evaluation, software and hardware choice and the progress of the latest procedure. Then, model assessment involves performing a sample (demo) in a workshop or in a real-world application to confirm that the system built for the RFID equipment is efficient, prepared for implementation and that workers fully understand both the approach and the system. Stage five, application, requires the contracting and establishment of software and hardware structures, in addition to management of change, education and training, and system execution. Finally, stage six involves constant assessment and continuing enhancements, achieved by the evaluation of system performance in line with the pre-determined goals.

Poulsen (2010) offers a complete structure with a ten-stage RFID application. In the first step, it is necessary to establish sufficient opportunities by evaluating existing and forthcoming industry procedures and to decide which characteristics are capable of improvement by executing and utilizing RFID. Stage two involves creating a structure to execute the corporation's preferred method. An RFID application has to be managed as a method-development plan, and awareness of crucial procedures and precisely how the RFID equipment will assist are essential components for effective execution. In the third stage, the designers of the system should identify and decide upon the system needs, the major concerns of which involve hardware, software, RFID tags, environmental factors, control, security issues, network, reliability output and protection. It is essential to produce a needs file, which explains the desired procedure movement and specific requirements to apply the procedure. The fourth stage involves gathering and evaluating the required spot information, by directing a cross-study (survey) which includes RF range evaluation to identify any affecting or challenging indicators in the field and an objective examination to locate and install receivers and readers. Then, it is essential to efficiently incorporate the numerous tools used in the structure and system. The goal would be to use bar codes and data which are readable by the human operator whenever required, as these provide a reserve in case the RFID reader or chip malfunctions. Furthermore, bar codes and data can be utilized in components of the procedure in which the usage of an RFID client is not possible. In the sixth stage, the execution procedure performs an assessment and selects the appropriate codes (tags) according to the specifications of the project and an appraisal of repeatability and quality. Next, it is important to determine the data needed for the system. This stage encompasses the preliminary presumed key benefits of RFID, which is the capability to store information on the device (tag) itself, even though this element is not needed by all the functions and applications. Stage eight involves correctly establishing and setting up the essential tools and equipment. A system of RFID employs a mixture of power, ethernet data and coaxial cables. Once set up, it a sufficient schedule for the analysis of software applications needs to be developed, assessing the findings and making adjustments as required to attain the required outcomes. Finally, the project team should document and archive the lessons learned from each new RFID project.

Similarly, as discussed above, this five-step process for RFID applications becomes an evaluation criterion for deployment readiness early in the process. The key is to evaluate whether you are positioned to deploy readiness; In general, once the needs and requirements are in place, the extent to which the organisation is prepared to deploy readiness needs to be accurately measured.

2.8.2 Assessment of deployment readiness

There are several approaches to measuring deployment readiness. These include the analytical network process (ANP) (Razmi et al., 2009), fuzzy cognitive maps inference (Ahmadi et al., 2015), and a combination of fuzzy cognitive maps (FCMs) and the fuzzy analytical hierarchy process (FAHP) (Ahmadi et al., 2015). In Javahernia and Sunmola (2017), a simulation approach to readiness assessment is taken to more easily capture the complexities involved in modelling manufacturing processes and their operations. Table 2 contains a list of approaches for assessing (measuring) deployment readiness compiled from existing literature.

Table 2: Approaches for assessing (measuring) deployment readiness

Deployment readiness method	Citation
Questionnaires. Structural equation analysis using LISREL	Kwahk, K.Y. and Lee, J.N., 2008.
Fuzzy analytic network process. The ANP technique was extended into a fuzzy domain.	Razmi, J., Sangari, M.S. and Ghodsi, R., 2009
In a literature review, Results from the literature investigation were distilled to five prerequisites deemed. In a series of one-on-one discussions with senior members of the company, using these inputs, a questionnaire was devised to test.	Burdon, S., Al-Kilidar, H. and Mooney, G., 2013
Interview, Quantitative data	Nugroho, M.A., Susilo, A.Z., Fajar, M.A. and Rahmawati, D., 2017.
Spreadsheet tool.	Levovnik, D. and Gerbec, M., 2018
INQA models in particular area for ERP are reviewed and a comparison between them was carried out.	Aarabi, M. and Mohammadkazem, M., 2014
Questionnaires	Vukovic, M. et al, 2013
systematic review was applied and resulted nine journal articles.	Lim, S.A.H. and Antony, J., 2013
Synthesised Six Sigma readiness evaluation model based on the BPC framework presented by Kettinger and Grover (1995)	Lagrosen, Y., Chebl, R. and Tuesta, M.R., 2011.
multicriteria algorithm	Galvez, D. et al, 2018
Fuzzy logic	Raju, R. and Antony, J., 2019
13 - Delphi study, Self-assessment Readiness scoring.	Lim, S.A.H. and Antony, J., 2016
Delphi study approach has been used in a variety of ways	Sunmola, F.T. and Javahernia, A., 2021

Table continues-next page.

Delphi and the analytical hierarchy process, from statistic and decision-making domains, respectively	Benssam, A., Nouali-Taboudjemat, N. and Nouali, O., 2016
a multimethodological approach including a systematic literature review, conceptual modelling and qualitative and quantitative methods for empirical validation.	Schumacher, A., Erol, S. and Sihn, W., 2016.
a description of a successful review at the two service providers. Applying the PMRR framework	De Waal, A. and Kerklaan, L., 2010
Simulation	Javahernia, A. and Sunmola, F., 2017.
Pearson correlations and multiple regression to explore the relationships between MIL and readiness for change	Hanpachern, C. et al 1998
FCMs and a fuzzy connection matrix to represent all possible causal relationships between activities. It then uses FAHP to determine the contribution weights and uses FCM inference to include the effects of feedback between the activities.	Ahmadi, S. et al 2015
Fuzzy cognitive maps (FCMs) fuzzy best–worst method (FBWM)	Irannezhad, M, et al 2021
fuzzy(based input derived from the stakeholders of the healthcare institution)	Narayanamurthy, G., et al 2018
AHP questionnaire. Fuzzy cognitive maps (FCM)	Pradana, S.I., et al 2015
open coding technique	Main, A. et al , 2015
fuzzy cognitive maps (FCM) and interpretive structural modeling (ISM). Data are gathered via the Delphi method FCM and ISM are also used to evaluate readiness.	Kalantari, T. and Khoshalhan, F., 2018.
concurrent engineering (CE)	Khalfan, M.M., et al 2001
The data were analysed using SPSS The parametric single-sample t-test and multiple regression were used to test the hypotheses.	Jafari, P. and Kalanaki, M., 2012.
conduct a qualitative study for a purpose of verifying the SIR dimensions identified in the literature review. Second, we develop a survey that assesses the five SIR dimensions and SI performance. Third, we validate the factor structure of the SIR concept as a third order formative construct with empirical data.	Yen HR, et al 2012
EFQM-based Model	Shafaei and Dabiri, 2008
7S McKenzie-based Model	Hanafizadeh and Ravasan, 2011
Fuzzy logic-based Model	Mottaghi and Akhtardanesh, 2010
IMPULS – Industry 4.0 Readiness	Lichtblau et al., 2015

Table continues-next page.

Empowered and Implementation Strategy for Industry 4.0	Lanza et al., 2016
Industry 4.0 / Digital Operations Self-Assessment	PricewaterhouseCoopers 2016
The Connected Enterprise Maturity Model	Rockwell Automation 2014
Industry 4.0 readiness and maturity of manufacturing enterprises	Schumacher et al. (2016)
Maturity and Readiness Model for Industry 4.0 Strategy	Akdil et al., 2018

2.8.3 Factors and Attributes of deployment readiness

Table 3 contains a list of process innovation deployment readiness attributes compiled from the existing literature. An emphasis in the compilation is on manufacturing enterprises. Several attributes are associated with the inputs for readiness assessment in related work. For example, Javahernia and Sunmola (2017) are plan-centric and include factors that can impact deployment plans. In the enterprise resource planning (ERP) setting, Razmi et al., 2009 identified three main areas that determine readiness to implement ERP, namely project management, organisational, and change management. The readiness for ERP implementation is further decomposed into project management, organisational, and change management areas, and they are broken down into project, vision and goals, systems and processes, culture and structures, and human resources categories. In smart factory settings, implementing innovation is recognised as a risky undertaking that can be difficult but with numerous benefits if the implementation is successful (Lenka et al., 2018).

Deployment of innovation is indirectly linked to Organizational Behaviour (OB) concepts within an organisation differently (Amabile, 1998). The organisational behaviour (OB) field helps better understand and manage people at work by studying human behaviours in organisations (King and Lawley, 2019). Organisational behaviour studies how teams work together and understand human behaviour, cultures, and organisational performance Verbeke, Volgering, & Hessels, 1998). For instance, companies build and foster innovative environments through culture, leadership, teamwork and motivation. Culture is one of the key OB concepts that link innovation deployment to organisations. Culture can support risk-taking, research, continuous improvement or hardy accept change. To be ready for innovation and have the ability to innovate, culture should be embedded in an organisation (Lim & Antony, 2013; Lim &

Antony, 2016). Leadership is another factor that links Organizational Behaviour (OB) to innovation deployment. Leadership support is important contempt to create a company's innovation culture. Encouraging employees to take risks and try different solutions requires effective leaders who are not afraid of new ideas (Lim, S.A.H. and Antony, J., 2013; Hasan et al., 2016; Lim & Antony,2016). Similarly, motivation and teamwork affect innovation deployment. Using different motivation strategies encourages employees to be more innovative. On the other hand, teams and teamwork enable collaborative discussion to generate new ideas and facilitate innovation.

According to Lenka et al. (2018), the key principles of smart factory implementation include the facets of people (cultivating digital people), process (introducing agile processes), and technology (configuring modular technology). Frishammar et al. (2012) argued that high-quality realization mechanisms, principally strategy, collaboration, and culture are critical to achieving desired process innovation outcomes. In an empirical measure of process innovation, (Gupta, 2021) used the following variables: imports advanced automatic quality restriction equipment/software, imports advanced programmable equipment, imports new process technology, imports new process technology, and adopts advanced CAD/CAM equipment.

Table 3:Attributes of Deployment Readiness found in the Literature

Attribute	**Example citations**
Market forces eReadiness.	Tan et al. (2007)
Purpose, Mission and Goals, alignment to Market forces.	Tan et al. (2007); Galvez, Enjolras, Camargo,Boly, & Claire, (2018).
Establishment of deployment plans and Implementation Vision, Business plan definition	Galvez, Enjolras, Camargo,Boly, & Claire, (2018); Lim & Antony (2016).
Strategy definition and Strategic Alignment, Link to customer and business strategy.	Hasan et al. (2005); Galvez, Enjolras, Camargo,Boly, & Claire, (2018).
Governance, Government eReadiness	Tan et al. (2007)
Standardize procedures for deployment.	Lim, S.A.H. and Antony, J., (2013).
Legal environment, Government policy and vision - Regulations	Benssam et al., (2016); Galvez, Enjolras, Camargo,Boly, & Claire, (2018).
Organization opens to new ideas (encourage innovation) knowledge sharing culture.	Lim, S.A.H. and Antony, J., (2013).
Organization Structure, Capability, Barrier	Rohayani, (2015); Adrian et al., (2017); Galvez, Enjolras, Camargo,Boly, & Claire, (2018); Razmi et al., (2009)
Support services overview	Galvez, Enjolras, Camargo,Boly, & Claire, (2018).
Acquired leadership abilities, Understand and support, Management and Leadership	Lim, S.A.H. and Antony, J., (2013); Hasan et al. (2016); Lim & Antony (2016).
Ability to communicate vision and mission	Lim & Antony (2013); Antony, (2014)
Ability to influence cultural readiness for change.	Lim & Antony (2013)

Table continues-next page.

Willing to assess and accept changes.	Lim & Antony (2013)
Ability to handle staff with poor performance.	Lim & Antony (2013)
Aggressive about setting up targets and achieving them.	Lim & Antony (2013)
Resilient and able to deal with frustration.	Lim & Antony (2013)
Knowledge of new process	Rohayani, (2015)
Infrastructure	Benssam et al., (2016)
IT Partnership	Hasan et al. (2005).
Maturity of the innovation - Technical maturity	Lim & Antony (2013)
Training (Education Requirements and Policies), coaching and learning opportunities, Training & education at all levels in the organisation	Lim & Antony (2013); Hasan et al. (2005); Lim & Antony (2016).
Organization encourages process ownership.	Lim & Antony (2013)
Employees feel free to report information on errors and defects.	Lim & Antony (2013)
Employees are motivated to self-enhance and adopt a learning culture and educate on process capability indicators.	Lim & Antony (2013); Lim & Antony (2016).
Commitment to deployment and Assign Responsibilities.	Lim & Antony (2013); Razmi et al., (2009)
Organization promotes the involvement of all its employees in quality and CI.	Lim & Antony (2013);Tan et al. (2007)
Availability of reward system and educational level of employees.	Lim & Antony (2013)
Motivation, and HR system and Human Capability.	Rohayani, (2015); Benssam et al., (2016); Adrian et al., (2017)
System Quality and Organisational process maturity.	Adrian et al., (2017); Galvez, Enjolras, Camargo,Boly, & Claire, (2018).
Availability of scientists and engineers and Technical skills development.	Galvez, Enjolras, Camargo,Boly, & Claire, (2018); Dumitrasco, (2018)
Experience, selecting the right people.	Antony, (2014)
Attitudes - Habits.	Rohayani, (2015)
Skill, Employees' knowledge, and skills.	Rohayani, (2015); Lim & Antony (2016).
Technological resources and Availability of latest technologies.	Tan et al. (2007); Nugroho, M.A., Susilo, A.Z., Fajar, M.A. and Rahmawati, D., (2017); Dumitrasco, (2018).
IT Partnership, Subcontractor engagement.	Hasan et al. (2005)
Decisions made based on facts.	Lim & Antony (2013)
Proactive quality system.	Lim & Antony (2013)
Data Source, Data Management and Data and Information Quality.	Hasan et al. (2005); Adrian et al., (2017)
Analytics Capability and Basic consideration of IT usage.	Adrian et al., (2017)
Potential value analysis.	Galvez, Enjolras, Camargo,Boly, & Claire, (2018).
Communication support design.	Galvez, Enjolras, Camargo,Boly, & Claire, (2018).
Project structure, Availability of project selection procedure and Presentation of the project.	Lim & Antony (2013); Galvez, Enjolras, Camargo,Boly, & Claire, (2018).
Production process sophistication - Determination and documentation of core value process.	Lim & Antony (2013); Dumitrasco, (2018).
Understand the processes and its workflow.	Lim & Antony (2013)
Protection of innovation.	Galvez, Enjolras, Camargo,Boly, & Claire, (2018).
Communications tools implementation.	Galvez, Enjolras, Camargo,Boly, & Claire, (2018).

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Impact on equipment evaluation and value chain evaluation - Value chain breadth.	Galvez, Enjolras, Camargo,Boly, & Claire, (2018); Dumitrasco, (2018).
Distribution modes design- Control of international distribution - Local supplier quantity and quality.	Galvez, Enjolras, Camargo,Boly, & Claire, (2018); Dumitrasco, (2018).
CI is aligned with business strategy.	Lim & Antony (2013)
Project selection criteria, Adequacy between the strategy and the project, Process selection and prioritisation.	Lim & Antony (2013); Galvez, Enjolras, Camargo,Boly, & Claire, (2018); Lim & Antony (2016).
Project management skills: setting agenda, setting, and keeping ground rule, determining meeting roles and responsibilities.	Lim & Antony (2013)
Financial, Budget elaboration and Financing plan definition, financial risks and Financial security of partners, Resource Allocation.	Rohayani, (2015); Galvez, Enjolras, Camargo,Boly, & Claire, (2018).
Deployment (planning) - Treasury plan, Investment plan.	Galvez, Enjolras, Camargo,Boly, & Claire, (2018); Main et al., (2015).
Project Championship - management commitment and resources.	Antony, (2014)
Establish comprehensive measurement mechanism for the process and product performance, Reliable tools to measure and Valid measurement system - Performance measures (key internal and external) identified, defined, and developed.	Lim & Antony (2013); Lim & Antony (2016).
Evaluate process performance and evaluate organisational/operational performance - Justification of process owners, responsibilities, authority, and process performance targets.	Lim & Antony (2013)
Training.	Main et al., (2015).

2.9 Research Gap

Assessment of readiness is usually performed post-system requirements and before the implementation phase. The published literature contains no methodology for deploying manufacturing process innovation, and this is one of the gaps this research aims to fill. A five-step methodology has been developed for innovation deployment as part of this research. The methodology is illustrated in Figure 14.

Figure 14:Framework of the methodology

The first step is to decide (and agree on) the goal of the deployment. From the perspective of the manufacturing process, this will mean a specification of the objectives of the innovation initiative, the reference point that is used to assess the success of the deployment, and any operational constraints that may be placed on the deployment. The second step is to establish a deployment plan, i.e., a clear image of the deployment plan, and how to achieve its goals. The deployment plan shows the scope and execution of the project planned for deployment. The plan can cover both strategic and operational aspects. For example, at the strategic level, the plan should state the innovation deployment strategies, e.g., direct, parallel, or phased deployment, and the risk response strategies. At the operational level, the plan clearly defines the actions for deploying innovation and includes deployment schedules, stakeholder engagement, roles, and responsibilities.

The third step assesses the state of deployment readiness and is divided into two sub-steps, namely, measuring deployment readiness and operational acceptance testing (OAT). OAT can be used to examine deployment readiness and to test the overall operational capability of the innovation initiative and deployment process. In this context, the objective of OAT is to confirm that the innovation and its implementation meet its operations requirements and can also be used to offer confidence that the manufacturing operations and processes will work as intended. In other words, they are operationally fit for purpose, during and post-implementation. The resulting level of deployment readiness and outcome of the acceptance test decision is used in the fourth step to explore areas of improvement. If there are areas to improve, the fifth step redirects back to the third step; otherwise, the deployment plan is accepted and authorised.

2.10 Chapter summary

In this chapter, the concept of innovation was described based on dimensions such as Radical, Incremental, Continuous, Administrative and Technological and Product and Process. The innovation process models were also outlined, considering the various generations (1G – 5G) that have evolved in recent decades. In addition, the diffusion of innovation, its implementation and continuous improvement were explained. Furthermore, this chapter helped develop innovative initiatives for implementing deployment readiness in manufacturing companies. The next chapter will describe the methodology used for this research.

3 Research Methodology

This chapter identifies the methodology employed to help achieve the research aim and objectives of the study. The chapter explains the process followed to collect the required data and outlines the reasons behind the choice of certain methods, techniques, and approaches. Additionally, it includes the rationale for implementing this methodology. This chapter has nine sections. Section 3.1 begins with an introduction to the various methods and tools used in the research. Section 3.2 discusses the type of research that applies to the research of social science. It starts with an outline of the deductive and inductive types of research, before moving on to offering a rationale for the approach chosen for this research. Section 3.3 presents the research method of the survey and explains the advantages of utilizing the stated technique for this research. Section 3.4 presents the questionnaire as the chosen research tool, its design, and the procedures for carrying out the questionnaire survey. Part 3.5 presents the Delphi study method, which is a step-by-step Delphi method of research and its considerations. This is followed by a recommended procedure of connecting the Delphi method of research to the academic type for this research. Section 3.9 describes Fuzzy logic and the related case study design and its objectives, as well as the selection and data collection processes used in this research. Section 3.10 explains the moral and ethical concerns that have been taken into account in this study. Part 3.11 concludes with a summary of the chapter and emphasizes appropriate responses and feedback that is integrated into this study (research).

3.1 Introduction

In the literature, scientists have used various meanings to identify and explain the methodology of the study and the method of study. Hussey and Hussey (1997) describe the study method as the whole procedure contained in the research. Clough and Nutbrown (2012) describe a study as a method of examining and researching a problem or occurrence. Leedy and Ormrod (2005) define a study as an established method of gathering, examining and translating information to realize a problem or occurrence. Saunders et al. (2009) posit a study as a process which is systemic, wherever information is collected and interpreted in a manner that assists the scientist in solving the study problem and attain the goals of the study.

The methodologies used in this study are: i) a literature review of the published literature, compiled in the previous chapter to determine the main steps involved in deploying manufacturing process innovation; ii) a survey questionnaire to develop a conceptual framework for manufacturing process innovation deployment readiness and examine the interactions between the key influencing factors; iii) Delphi study to identify factors, attributes and dimensions that determine the assessment of Process Innovation Deployment Readiness in Manufacturing; iv) Using the outcome of Chapter four and a fuzzy logic approach to developing an assessment method and a Case study to validate the assessment method developed and report on its practical significance to manufacturing managers.

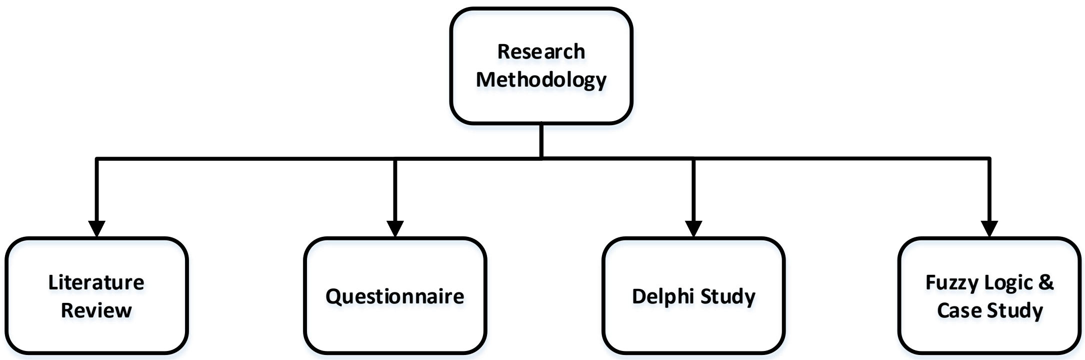


Figure 15: RESEARCH METHODOLOGY

3.2 Research Approach

It is important that the research carefully establishes an ideal research approach as it is identified as one of the most pertinent research decisions (Blaikie & Priest ,2019). Research has shown that there are four approaches used in developing research conjectures and are classified into four categories: induction, abduction, deduction and retroduction. The inductive and deductive research approaches are discussed next in this research (Myers & Liu, 2009). These approaches provide different guidelines for addressing the research gaps (Blaikie & Priest, 2019; Ngwenyama, 2014).

3.2.1 Deductive Research Approach

This research approach "is a study in which a conceptual and theoretical structure is developed and then tested by empirical observation" (Collis & Hussey, 2013). It can also be described as a theory-testing process which is initiated by analysing existing knowledge. The deductive process starts with the testing of available theory or developing the hypothesis from an existing theory by collecting specific data, testing the hypotheses, and then confirming or modifying the theory. The aim of this attitude is to apply the hypothesis to describe the connections among concepts and variables. Thus, logical research moves from the general to the specific (Collis & Hussey, 2013). This is generally functional in the research, which is quantitative wherever models and theories are shown as a set of variables that are designed into plans or theories to signify the relations between the variables which are supposed (Creswell, 2014).

3.2.2 Inductive Research Approach

The inductive approach "is a study in which theory is developed from the observation of empirical reality" (Collis & Hussey, 2013); it can also be described as a theory generation process. This approach starts with the collection of data, analysing of the data and then the generation of the theory. The aim of this approach is to create generalities regarding the nature of the relationships among assessed traits of persons and societal trends (Blaikie, 2010). The inductive approach moves from individual observation to broader generalisation and theory (Collis & Hussey, 2013). This is commonly applied in the research, which is qualitative, wherever assumptions and theories are typically the "ending point" of the collection of the data and evaluation procedure (Creswell, 2014).

3.3 Research Methods

The main power of study work is the variety of research methods. Research methods can be described as a procedural framework within which research is conducted. It describes an approach to a problem that can be put into practice in a research process, which can be formally defined as an operational framework within which the facts are placed so that their meaning may be seen more clearly (Bryman et al., 2007). There are different classifications of research methods; the most common distinction is between the quantitative and the qualitative approaches (Myers & Liu, 2009).

A quantitative study is organised and systematic research, performed in an experimental structure, of an occurrence that is apparent in nature and happens through numerical, statistical, or techniques which are computational (Bryman et al., 2007). Research which is quantitative is commenced with the objective of improving and utilizing models which are mathematical, concepts and theories, and/or theories connected with this trend. The core of this study technique and method is the procedure of size, as it suggests a correlation between practical examination and the scientific and mathematical extraction of numerical organisations. None of the data that is mathematical in nature (eg numerical in percentage) is called numerical (Yin, 2004) but would be impartial and generally efficient in a bigger company or populace. In other words, the information is examined by utilizing indicators and anticipating the digits to deliver outcomes that are impartial and can be widely applicable to some bigger team populace. The study, which is qualitative, is a comprehensive study which involves various techniques of research. The purpose or objectives of this qualitative study are to be able to encompass differences dependent on the experience of the subject, for example, a seeker for the psychologist to gather comprehensive and detailed data on human behaviour and the purposes regulating such manner. The technique of qualitative study investigates the “how” and “why” of choice creation, not only the “where”, “what”, “who”, or “when”, with the chance of a powerful intolerance in specific areas as sociology, (e.g. for making and knowing the plans of administration or the social benefit afforded). It might begin as an approach (which is a nature-based theory) wherever the scientist might not have any previous knowledge or awareness of what is taking place.

3.3.1 Choice of Research Methods

There are a number of academic issues that the scientist has recognized from the information accessible in relative to perceptions, deployment, application, and evaluation of instances of manufacturing process innovation. In particular, the information (literature) is restricted to the explanation of aspects of success and steps of the manufacturing process innovation deployment. Thus, this is the primary logic determining the choice of study method for the research. The research method applied to this study primarily focuses on a survey questionnaire for the first data collection phase, then a modified Delphi study for the second phase (the expert panel), and thereafter a Fuzzy logic method for the third phase, followed by a case study research analysis for the final phase. These are discussed in more detail below.

3.4 Questionnaire Survey

The method of survey research is selected for this study to support the researcher's quantitative view, which is focused on testing the theoretical framework developed in chapter five. Surveys can be described as a procedure of collecting standardised data after an example of individuals who have been chosen to embody a specified group (Burns & Burns, 2008). Because a process that allows a methodical gathering of data regarding persons or groups in society, a survey affords evaluations of the gathered data and conclusions as an example (Creswell, 2014). There are two common data collection techniques which can be used with the survey approach, interview and questionnaire (Blaikie & Priest, 2019). In the first phase of this study, a literature review explored the body of knowledge (Collis & Hussey, 2013). Thereafter the study developed an online questionnaire survey which was used to collect primary data from organisations to test the study hypothesis and generalise the findings.

An online questionnaire survey has numerous advantages and possible disadvantages, as argued by many researchers in the literature (Fricker & Schonlau, 2002). The positive factors for using an online questionnaire are that it is flexible, convenient, and can reach participants without any geographical boundaries. The simplicity of this administration can help the researcher to recruit more participants and thus increase the size of the sample size. Online questionnaires can be accessed and answered at a time that is convenient for each participant, and they are free to answer the questionnaire without any time, location, or power restraints (Evans & Mathur, 2005). Moreover, an online questionnaire is cost-effective for the researcher, as it does not require using postal services or interviews (Evans & Mathur, 2005).

However, online questionnaires have some potential disadvantages, such as the email being labelled as spam, unclear answering instructions, their impersonal nature, and privacy and security issues (Evans & Mathur, 2005). Participants who are unclear about how to answer the questions are unable to ask for help as the researcher is not physically available. Moreover, participants may question the confidentiality of their answers and how they will be used. In this research, we are aiming to overcome these disadvantages.

While assessing the benefits and drawbacks of this technique, the writer believes that the benefits outweigh any disadvantages for this study. Particularly, a focus on certain specialists is more feasible for gathering information through an online survey and the use of emails is more efficient in terms of expense and time required to conclusion.

3.4.1 Questionnaire Designs

The path a scientist takes in order to set up his questionnaire can be described as the questionnaire shape. The process, however, is a long one and needs a theoretical standard that assists in streamlining the emphasis of the research (Forza, 2002). It is believed to be a highly demanding and challenging form of research survey, although the testing theory allows the re-use of methods, descriptions, and outcomes from preceding surveys (Forza, 2009).

This study collects data online through self-administered questionnaires. Thus, a proper electronic survey means was required. When evaluating various online means, it was agreed to make use of the Bristol Online Survey (BOS). A BOS Survey allows scientists to simply create their specific surveys by employing practice patterns and offering a lot of graphic assistance for the subjects. Moreover, a BOS Survey adopts the entire request and notice procedure. BOS, in addition, encourages the organisation of unnamed studies so that contributors cannot be ignored. Findings can then be copied into professional statistics programs, for example, SPSS, or spreadsheet applications, such as Excel, for additional evaluation. This questionnaire can be found in Appendix A of this thesis.

The questionnaire was designed to study and explore further the areas identified from the conceptual framework. The questionnaire consisted of twenty-seven (27) questions, shown in section 8.1 as an appendix. The structured questionnaire themes are as follows:

The first part confirms whether the respondent has experience with process innovation, and the second part consists of 7 sections (shown in table 4) and would collect data about the attributes (factors) in the conceptual framework, i.e., deployment plan, Mix and labour flexibility, and Climate for innovation. The questionnaire was pre-piloted with a selected group comprising of academics and practitioners before being sent out to ensure that the questions were clear and well formulated.

All the measures from sections A-F are based on a seven-point Likert scale. The responses are entered into the SPSS software to generate different analyses. Finally, to test the research hypotheses, hierarchical regression analysis will be used (Oke, 2013), to help account for the variance created and the interaction effects and operational managers that work in an innovation process.

Table 4:Variables in this study

Section A: Mix flexibility	Section D: Climate for innovation
Section B: Labour flexibility	Section E: Innovation Deployment Preparedness
Section C: Deployment plan	Section F: Innovation Deployment Full Readiness
Section G: Perceptions of process Innovation Deployment	

3.4.2 Variables and their nominal definitions

This study recognises the variables or structures for the research of the survey, involving their corresponding operating explanations. Commonly, variables found in a model which is theoretical give an understanding of the study question and characterise the facet of the challenge that the research seeks to describe (Bryman, 2016). The explanations of variables are crucial to improving significant quantities of theories contained by the theoretic type. As of the importance of precise numerical analyses in quantifiable experiments, the meanings of variables similarly need to be established obviously and properly (Wacker, 2004). According to the conceptual framework in Chapter Five, figure 18, the main variables identified for this study were: Deployment plan, Mix Flexibility and Labour Flexibility, Climate for Innovation, Innovation

Deployment Preparedness, and Innovation Deployment Full Readiness (shown in table 5).

Table 5: Variables in this study and their respective nominal definitions

	Construct	Definition
1	Deployment plan	A deployment plan is a detailed proposal for implementing an innovation initiative in a target environment (Created by the researcher). A deployment plan can be either: a) explicitly set out and formalised, or b) informally set out, i.e. implicit
2	Mix Flexibility	*The ability of the organization to produce different combinations of products economically and effectively given certain capacity (Zhang et al., 2003); Boyer and Leong (1996); Sethi and Sethi (1990); Gupta and Somers (1992); (Oke, 2013).*
3	Labour Flexibility	The ability of the workforce to perform a broad range of manufacturing tasks economically and effectively (Oke, 2013), Upton (1994), Hyun and Ahn (1992), Ramasesh and Jayakumar (1991)
5	Climate for Innovation	An environment that is the outcome of the practices and reward systems that are put in place to recognize and encourage creativity and innovation. Oke (2013), Scott and Bruce (1994)
7	Full Readiness	Fully ready prior to deploying the process innovation initiatives.
8	Innovation Deployment Preparedness (IDP)	IDP is the state of readiness. There is a comprehensive deployment team in place. AND There is a deployment framework selected to guide the implementation innovation process.

3.4.3 Population, Participants and Sample

The process of sampling is picking a small number of participants from a bigger team or group with the intention of taking a broad view from the example (the smaller one) to the people (the bigger one). To create a convincing presumption regarding the people, it is necessary to pick an example so that it is typical of the entire populace (Gliner et al., 2011). This study aims at achieving the above objectives using the subsequent stages as recommended by Burns & Burns, 2008 and Gliner et al., 2011: a) Describing the objective populace (Defining the Target Population), b) Recognizing the frame of sampling (Identifying the Sampling Frame), c) Choosing and employing a technique of sampling, and d) Specifying the size of the sample.

3.4.4 Defining the Target Population

This research focuses on professional manufacturing managers working in British manufacturing who have experience implementing process innovation in manufacturing organisations. The questionnaire must be completed by a manufacturing manager or executive staff employed in the company who are regarded as experts in their specified manufacturing sector and highly trained in the technical and practical implementation of enterprise applications (Chang et al., 2013; Mitra & Mishra, 2016). For this study, the target respondents are those professional manufacturing managers, for example, in production, manufacturing, assessment, protection and maintenance, tactical development, as well as purchasing. It is better for those who respond to have sufficient expertise and knowledge in producing expertise acceptance actions and activities in the company. The wide exposure of management positions in the focus participants is intentional in concordance with the insight that the adoption of technology is tactical decision-making of firm-wide workout and not restricted to individuals in specific professional positions (PapkeShields & Malhotra, 2001). This research similarly trusts the perception of respondents' applicability for the study (to he/she positions in the corresponding companies) to assist in alleviating any primary challenge of finishing the survey (questionnaire), therefore, improving involvement (Frohlich, 2002).

3.4.5 Identifying the Sampling Frame

Based on Burns and Burns (2008), the frame of sampling signifies ‘a complete file of the objective population’. In this study, the populace was retrieved using various sources of a dataset of UK information systems. Primarily from the FAME database, a random sample was depicted to represent a wide variety of managers in the manufacturing sector of the UK. The list was screened and revised based on the accessibility of the availability of active online and offline contact data to facilitate the follow-ups and ensure a high response rate. The seven hundred manufacturing companies were selected randomly to construct the sample. Consequently, 700 questionnaires were sent to manufacturing managers in various manufacturing sectors and industries. From the 700-survey distributed, ‘useful responses were obtained’ from 101 manufacturing managers, each from one company. Due to the system used for data collection (Bristol Online Survey), the system automatically did not accept any incomplete responses. The 101 usable responses from a population of 700 companies ready for further analysis represent an overall response rate of 14.4%.

3.4.6 Defining the Sample Size

The size of the sample and the number of answers affects the value and precision of numerical conclusions. Therefore, taking these into consideration is a vital stage in a study. As stated above, this research managed to collect 101 possible participants, who comprise the total sample size in this study. The writer examines various attitudes for deciding the number of responses required to make up valid interpretations. Gliner (2009) and Saunders et al. (2007), for instance, suggest 30 as the minimum acceptable number of contributors to draw precise numerical conclusions. As Baruch & Holtom (2008) describe comparatively superior binary sizes of 50 to 80. Sheehan (2001) discovered that the median answer ratio to email surveys is declining and registers an average answer ratio of 24% in the year 2000.

3.4.7 Questionnaire administration

The use of the Web as a channel for survey distribution has increased dramatically in recent years. The methods and approach to analysis intended for this survey will be largely like those reported by Oke (2013), except that the survey will be done in a single wave instead of multiple waves.

The questionnaire was administered online via Bristol Online Surveys (BOS). An introductory email was sent to the various participants requesting their participation in the research studies. The email outlined the purpose of the research undertaken and the aim of the questionnaire survey. The participants were assured of the confidentiality of their responses and were given the choice of discontinuing their participation in the project at any time if they wanted to. These participants are known to have implemented or are in the process of implementing innovation or improvements of some kind. A sample of the introductory email to the participants has been provided in section 8.2 as an appendix.

An initial list of all manufacturing firms with operations in innovation was drawn from the Manufacturing sector of England web directory. The survey questionnaire was administered via an online site and distributed to 700 managers employed in the manufacturing industry within the UK randomly By the end of the fourth week after delivery of the questionnaire, the study had collected 35 valid responses. According to the quantity of chosen participants, this amounts to a less than 5 per cent response. According to Bryman (2016) and Baruch (1999), the response rate tends to be low when managers are the focus of the survey. Even as stated previously in this part, this study aimed to reach respondents in organisational positions. A follow-up email was also delivered to the participants 42 days after the initial distribution of the questionnaire, which drew a further 17 answers, bringing the total number of responses to 52. A third and final request was sent out some months later, drawing replies from a further 49 participants, bringing the final participants' response to 101. This represents a 14.4 per cent response rate. The summary of the respondents is presented in Table 6.

Table 6: summary of the respondents

	First Request	*Second*	*Third and Final request*	*Total*
Usable Response	35	17	49	101
Total	35	17	49	101
Total Number of samples	35	17	49	101

**Response Rate = total number of responses/total number of the study sample*

3.5 Non-Response Bias

Numerous assessments have been used to examine the non-reply representativeness and bias of the sample for this research. Based on Forza (2009), non-answers are able to restrict the outcomes and the generalisability of research. One of the methods of reducing non-answer impacts on the gathered information is to analyse all the specific answers to verify reliability in the reports of participants. The investigator boarded on a workout to distinguish non-participants and to monitor differences among the participants (Forza, 2009). This assessment workout for this research was performed during the process of collecting data over a seven-month period.

Another test was undertaken to check for non-response bias by comparing the early and late respondents (Oke et al., 2013; Armstrong & Overton, 1977). This analysis reveals that there are no significant differences between the first and later replies in the entire sample. Moreover, we applied the single common factor analysis using SPSS. This indicated that 38.806 per cent of variance was explained by a single component factor of all items. This suggested that the data did not exhibit significant common method bias (Podsakoff et al., 2003).

Due to the system used for collecting data (Bristol Online Survey), the system automatically did not accept any incomplete responses. A response rate of about 14.4 per cent is equivalent to comparable experiential research in industrial knowledge implementation, for example, Swamidass & Kotha (1998); Beaumont et al. (2002); Swink & Nair (2007); and Das & Nair (2010).

3.6 Quality Criteria

The criteria used to check quality in this study are validity and reliability, which are valuable for measurements in the study. They are discussed in the subsections below:

3.6.1 Reliability and Validity

The point is reached at which collecting data methods or evaluation processes will generate stability and strength, allowing conclusions to be duplicated (Burns & Burns, 2008; Saunders et al., 2007). In broad terms, reliability can be realised as the level of duplicability of volume outcomes (Diekmann, 2004). Nevertheless, such trustworthiness appraisals are frequently not achievable. Two accomplishments of the same format at a similar point in time are frequently not possible. One reason is that only one contributor replicates the survey immediately after finishing the first (original). Thus, consistency must be evaluated as an academic structure, which can just be assessed by estimation (Rammstedt, 2004). There are various techniques to achieve this. The highly popular reliability techniques are the “split-half reliability method”, “internal consistency method”, “test-retest reliability method”, “test-retest reliability method”, and “parallel reliability method” (Burns & Burns, 2008; Diekmann, 2004; Rammstedt, 2004). For the aim of this research, we have evaluated the test-retest technique as the most appropriate method to verify the consistency of the outcomes. In the method of test-retest, the questionnaire will be re-performed following a specific period of time (Diekmann, 2004). The relationship among the weights from both points of time determines the test-retest reliability.

Burns and Burns (2008) emphasize the significance of characteristics among validity and reliability. They discuss that “while consistency (reliability) correlates to the precision and strength of a gauge, validity communicates to the suitability of the size to evaluate the structure it intends to assess” (Burns & Burns, 2008). In related literature, validity is frequently divided into inside and outside validity. Inside (internal) validity is identified as ‘the extent to which the outcomes of an example are exchangeable to a populace’ (Burns & Burns, 2008, p. 426). Occasionally external validity is mentioned as ‘generalisability’ (Saunders et al., 2007). The amount of this generalisation differs on the interpretation of the example (the validity of population) and the real circumstances (the validity of ecology) (Burns & Burns, 2008; Gliner et al., 2009). On the other hand, the validity of Internal as a substitute respects the extent to which "any changes or associations can be assigned to the variable which is independent and not to any other aspect" (Burns & Burns, 2008, p. 427). This indicates that the validity of internal is affected by the issue of an instrument of measurement essentially calculating that for which it was meant. The internal part normally includes the following three attributes: the validity of the content, the validity of criterion-related (validity of analytical and simultaneous) and the validity of construct (Burns & Burns, 2008; Creswell, 2009; Diekmann, 2004).

3.7 Data analysis

The main aim of this research is to investigate factors associated with readiness to deploy process innovation in manufacturing and to understand the contributions of the factors in achieving the target deployment readiness level. This aim is accomplished by conducting an analysis of the data obtained from the manufacturing firms in the UK. Accordingly, there is a necessity to subject the dataset to a few preliminary tests. Furthermore, to validate the conceptual models and verify the proposed research hypotheses presented in Chapter 5, the SEM was conducted using AMOS version 26.0, which has been accredited by many scholars.

Once the requirements of the research plan and data collection were determined, the subsequent action in the study and research plan is the analysis of data. For this reason, the researcher investigates important issues such as addressing missing data, dealing with outliers, and testing the normal distribution of variables (Tabachnick & Fidell, 2013, Kline, 2005, Hair et al., 2010). The outcomes of this section give a broad image of respondents' information and their answers to the survey tool. In this research, the SEM method is mainly accepted to assess the routes in the basic and structural models.

Chapter 5 first outlines the basic concepts of structural equation modelling (SEM) before describing the detail of analytic methods utilising SEM, functional factors for its implementation, and factors assessing the structural and measurement models Delphi Study.

3.8 Delphi Study

The Delphi study approach was also used in this research. This approach has been used in a variety of ways; some researchers categorise the Delphi as a data collection technique, while others refer to it as a research method (Dahlia Fernandez et al., 2017; Cho HK et al., 2003). The Delphi method is a combination of best practices that allow participants to deliver their thoughts through various means of communication while analysing a complex problem (Sheridan, 1975). This was developed in the 1950s by the Rand Corporation as a data collection method designed to obtain comparability and discover opinions and consensus regarding topics in a discussion (Baretta, 1996; Green, 1999). The Delphi method is designed to encourage discussion to obtain answers from experts and, at the same time, allow them to refine their ideas and opinions during the discussion (Adler, 1996). This approach also provides an opportunity to gain a better understanding of the topics covered (Watson, 2008). Generally, participants in a discussion have a strong interest in the topic, bringing valuable knowledge and/or experience to that discussion (Delbecq, 1975). Delphi's approach involves a series of 'rounds' of data collection. At the end of each round, the model or concept to be tested is revised. These rounds continue until there is an agreement or disagreement that cannot be resolved (Williamson, 2002a). The feedback is then analysed, and another questionnaire is developed based on the feedback received. It is also important to have a robust selection for the expert panel and an approach for active and continuing participation in the discussion (Watson, 2008). For this thesis, the Delphi approach was applied. An online expert panel was established and moderated by the researcher. The researcher developed a list of questions based on the proposed model findings from the literature and posted them online for expert feedback.

3.8.1 General Steps of the Delphi Method

Generally, a Delphi is structured into distinct rounds and requires a qualified panel of experts. The first round may include questions that solicit quantitative and qualitative data but must ensure relevancy and validity for the study. After the administration of the questionnaire, the responses need to be analysed. With each successful round, the panel are asked to revise their original responses through feedback provided. This process can be repeated until an agreement is reached. Table 7 shows the steps taken to achieve a Delphi study. The research process, utilising the Delphi method, is based on four principles and includes:

- Experts (participants) are selected since they have the expertise in the studied issue.
- By gathering expert opinions through the process of multiple interactions, a consensus will be reached.
- To promote greater interaction and a reflective process, feedback is applied to the participants.
- Any solutions or future predictions will involve expert opinions (Plummer, Armitage, 2007).

Table 7:steps taken to achieve a Delphi studies

Test or Preparation	Identification, selection, and invitation of the study participants from the industry and academia
	Development of rules and schedule of the research
Round Zero	Identification of key themes and research opportunities for process innovation
	Introduction to the Delphi, Aims and objectives and presentation of the list from the literature. Summary of the results of the round zero and entering them into the questionnaire distributed in the first round
Round One	Distributing the questionnaire together with a summary statement of the results of the round zero Preparation of the report for the next round
Round Two	Consolidate Delphi round one factor and descriptors, given feedback from round one
	Preparation of the report for the next round
Round Three	Reconcile new/modified factors and agree to consolidate the list of factors and descriptors, given feedback from round two
	Analysis of the results of all rounds of testing
	Report of the survey results

3.8.2 General Methodological Considerations & Anonymity of Delphi participants

The process of recruiting the experts is initiated by the research team and involves drafting a list of potential experts from various professional groups, e.g., LinkedIn. Also, the process of gathering and maintaining a reasonable response rate is a critical objective of a Delphi study as it helps limit the effect of bias (Linstone & Turoff, 2002, Okoli & Pawlowski, 2004, Hasson & Keeney, 2011). The study dropouts are also managed at the end of every round. Anonymity allows free communication without undue social pressures to conform. Decisions are more likely to be based on the merit of the proposal rather than who made the proposal. Importantly, if judgments turn out to be unsuitable, participants do not lose face. Turnoff and Hiltz (1996) point out that anonymity allows experts of high status to produce questionable ideas and permits lower status participants to introduce ideas without fear of being rejected outright.

3.8.3 Delphi Study in This Research

As highlighted in table 7 above, the Delphi approach was used for this research. To implement the first phase, we invited 18 experts from the manufacturing sector in the United Kingdom. Among them were representatives from both academia and practitioners. Complete feedback from 12 experts was received. In this study, three rounds of emails took place. The participants were anonymous. The process was an iterative one that required evaluation and re-evaluation of data by determining possible themes and common ideas from the participants. After round one was conducted, in round two the researcher asked participants to identify areas of agreement, areas of disagreement, and any additional effective practices. From 12 experts, feedback from 10 experts was received. Based on the important feedback received from them, we then finalised the accepted factors. In round two, we also revised the list of factors and descriptors that recorded 50% or less acceptance to accommodate the feedback and research findings. Round three questions followed the same format until a consensus was reached regarding effective practices. Among the participants, there were people from different job positions, such as Researchers, Lecturers, Professors, Managers, Directors and CEOs from different organisations in the UK.

3.9 Fuzzy logic & Case study

The application of fuzzy logic to diverse manufacturing difficulties has grown rapidly over the last two decades. Fuzzy logic evaluates variables included in a set depending on their degrees of membership rather than absolute membership in its most basic form. Instead of precision and accuracy, fuzzy logic allows for some room for error. Inexplicit information can be integrated into fuzzy modelling, such as that obtained from inexact measurements or from imperfectly codifying expert knowledge.

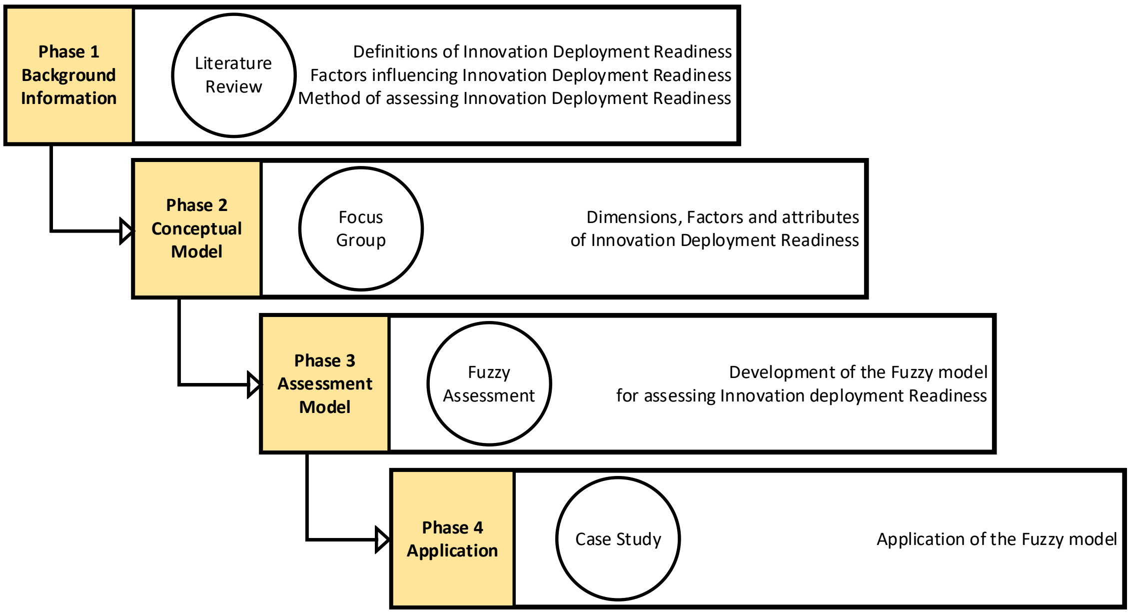


Figure 16:Research process and related methodologies

In essence, fuzzy logic tries to imitate the human mind in order to efficiently use approximate rather than exact reasoning modes. Fuzzy logic detects inaccurate relationships among concepts by allowing for imprecision in memberships. The fuzzy logic approach differs from "crisp logic," which is based on propositional logic and involves binary decisions and reasoning. Variables in fuzzy logic have a range of 0 to 1 and are not always confined to such binary limitations. Instead, a variable represents the degree to which it belongs to a fuzzy set. This is because fuzzy logic allows for imprecision in the model; it allows for the inclusion of imprecise inputs and thresholds (Homayouni et al., 2009). "Linguistic variables" like large and small, major and minor, and low/medium/high can also be incorporated into the model without having to be properly described. This is a powerful feature of fuzzy logic modelling because it allows for imprecise measurements to be integrated, such as existing expert knowledge in verbal descriptions (Turksen & Zarandi, 1999). The decision-linguistic maker's thought process is qualified and quantified, utilising fuzzy logic and approximate reasoning.

In this study, fuzzy logic is used because it is a straightforward technique to get a definitive conclusion based on vague, ambiguous, imprecise, or absent information (Olugu & Wong, 2009). Fuzzy logic is a representation technique for ambiguous or uncertain concepts. It serves as the foundation for a qualitative method to analyse complex systems' behaviour in which the modelled system is characterised using language rather than numerical variables. Fuzzy triangular or trapezoidal numbers can be used to represent linguistic variables. This research uses triangular fuzzy numbers (TFNs). TFNs are the simplest type of fuzzy number (Voskoglou, 2016). Their application in the literature has grown in popularity for challenges including supplier selection, inventory management, outsourcing, and distribution. (Kannan, 2018; Lamba & Singh, 2018; Shahbazi & Byun, 2021). Figure 17 shows how a TFN can be represented with three points: A = (a, b, c), where a, b, and c are parameters and membership functions that satisfy the following requirements:

(i) a and b are increasing function
(ii) b and c are decreasing function
(iii) $a \leq b \leq c$

$$\mu_A(x) = \begin{cases} 0, & \text{for } x < a \\ \dfrac{x-a}{b-a}, & \text{for } a \leq x \leq b \\ \dfrac{c-x}{c-b}, & \text{for } b \leq x \leq c \\ 0, & \text{for } x > c \end{cases}$$

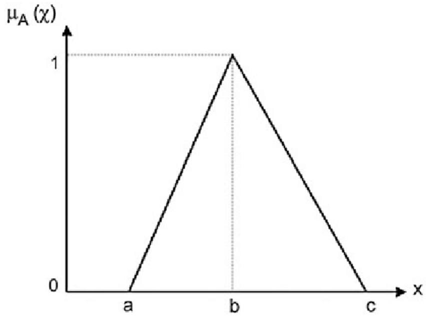


Figure 17:Triangular membership function

The two triangular fuzzy numbers A=(a,b,c) and B=(a 1,b 1,c 1). Below are the basic arithmetic operations performed on TFNs A and B (Gani and Assarudeen, 2012).

Addition, $A \oplus B = (a,b,c) \oplus (a_1,b_1,c_1) = \{(a+a_1),(b+b_1),(c+c_1)\}$

Subtraction, $A \ominus B = (a,b,c) \ominus (a_1,b_1,c_1) = \{(a-a_1),(b-b_1),(c-c_1)\}$

Multiplication, $A \otimes B = (a,b,c) \otimes (a_1,b_1,c_1) = \{(aa_1),(bb_1),(cc_1)\}$

Division, $A \oslash B = (a,b,c) \oslash (a_1,b_1,c_1) = \left\{\left(\frac{a}{a_1}\right),\left(\frac{b}{b_1}\right),\left(\frac{c}{c_1}\right)\right\}$

3.9.1 Case study

To validate the method developed for assessing deployment readiness, we have used a case study, which is one of the major research approaches. This is neither a gathering data technique nor a plan specification, but it is a strategy of research which is comprehensive (Yin, 2003). Robson (2002) defines the concept of a case study as "an approach(strategy) for doing a study which involves an experimental study of a specific modern occurrence in its actual-life context using multiple sources of evidence".

Researchers employ the case study technique as it covers circumstantial conditions that may be related to the phenomenon of their study (Yin, 2003). Case studies have been utilised in this research into the behaviour of the organisation, specifically in order to understand structural innovation and change, while creating cooperation between the inner forces and the outer environment (Cassell & Symon, 1994). A technical definition of a case study is an experimental study that believes a modern happening within the context of its actual lifespan, especially while the borders between perspective and happening are not obviously apparent (Yin, 2003). These qualities and improvements of the case study indicate that this sort of strategy for research fits the objective of this experiment and will improve the likelihood of reaching a solution in this study.

3.9.2 Case Study Objectives

The main aim of this case study is to capture and critically analyse the approach that the case study company has used to deploy the process innovation and relate it to the methodology proposed in this research. This will be done in three steps.

A. Obtain background information regarding the process innovation. Interview the relevant staff (middle management, shop floor managers and operational managers) in the case study company, with discussions and qualitative views on their reflection on the deployment process and implementation performance.
B. Document the approach that the case study company has used and the role of a deployment plan in the process.
C. Critically appraise the approach used by the case study company within the context of the proposed methodology and document the lessons learnt.

In this case study, relevant managers will be asked to provide a sample of the process innovation that they have implemented within the last three years.

3.9.3 Case Study Selection

The researcher tried to select businesses that would permit largely unrestricted access to a range of employees rather than allow only superficial contact. The former shows that: 1) candidates are eager to dedicate an adequate period to discover questions in feature; 2) there is an adequate number of candidates in the business to licence some authentication and reduce cross-checking or bias; 3) there exists a variety of candidates who cover the extent of the innovation activities of the company, and 4) the company possesses candidates with adequate knowledge to deliver well-versed thoughts. These conditions limited the options for businesses in terms of the case study. However, the company selected, operating in the manufacturing business, presents a very good practical foundation for the study. One case study can explain in depth the reality of an occurrence (Siggelkow, 2007).

3.9.4 Data Collection

Many resources can provide data. Nevertheless, it is claimed that questioning is the most important of all qualitative data collection techniques (Easterby-Smith, Thorpe & Lowe, 1991), and likewise, it is one of the highly valuable sources of case study information (Yin, 2003). Thus, the method of the interview was chosen as the most effective technique for the collection of qualitative data in this thesis. Additional evaluation of different materials from more resources was also used in this research.

3.9.5 Methods of Data Analysis

For the interview, the content analysis technique will be used to form the qualitative analysis, and to evaluate various conditions in the different organisations. A primary evaluation of the interview data, in other words, signals the potential comparative significance of various factors affecting innovation deployment, formulates a shape for the further comprehensive assessment of the interview records.

3.10 Ethical Considerations

The Code of Research Ethics at the University of Hertfordshire was followed for this study. Prior to starting the data collection process, research ethics forms were completed and submitted to the University of Hertfordshire Ethics Committee. For the questionnaire survey, a participant information sheet (PIS) was required, which was completed after obtaining ethical approval. PIS includes the research title, the researcher’s details, the aim of the research and, finally, a statement ensuring confidentiality and the voluntary nature of participation. The form was attached to the questionnaire. When respondents click on the online link to the self-completion questionnaire, they give their informed consent to participate in this study. If respondents choose not to participate, they can do so by closing the weblink browser. Respondents were informed that because replies were recorded anonymously, they would not be able to erase any data that they had already contributed in part or in whole. Questions in the first part of the questionnaire are about the respondent's profile, such as firm size, position, and the type of product the firm manufactures. These questions are meant to capture non-identifiable and impersonal data so that target responders may be certain that their identities will not be revealed. The survey data is stored online by BOS and can only be accessed by authorised users. In this case, only the researcher will have access to the research data. This is a feature of BOS's Survey Protection function. To restrict unauthorised access to the questionnaire and maintain data security, the researcher chose "By Invitation Only". Respondents are also told that participating in the survey poses no known or anticipated hazards to them. At the conclusion of the study, a copy of the final report on the survey results will be made available to the respondents as a reward. In both physical and electronic formats, all research data and administrative records are kept for at least ten years after the publication of this thesis, and these will be kept in a locked filing cabinet and encrypted in files on the department server at the University of Hertfordshire's School of Engineering and Computer Science.

3.11 Chapter Summary

This chapter started by introducing the research approach and research strategy in order to examine the theoretical foundations of this study. Research methods, the survey, the Delphi study and the case study were also reviewed. The study comprised an exploratory case study and adopted an interpretive approach to the qualitative data collected. The chapter provides detailed models of the three stages of data collection using the Delphi process, data analysis processes, and the case study. Furthermore, it explains the application of the conceptual framework to the data collection and analysis based on the three dimensions of change and three phases of implementation, which allow a chronological approach to the data analysis. In summary, to achieve the aim of the research, the methodology consisted of a single case study, questionnaires, interviews, and documentation that were used over nine months of data collection.

4 Dimensions of deployment readiness

4.1 Introduction

The challenge of assessing readiness to deploy process innovation in manufacturing, particularly during pre-implementation stages, can be addressed first by capturing the factors that influence readiness to deploy the process innovation. This is the focus of this chapter. The approach taken is to build on the attributes of process innovation deployment gathered from the literature and reported in Chapter 2 of this thesis. Through a Delphi study, a set of experts in the manufacturing industry are then used to consolidate the attributes into factors and dimensions of process innovation deployment readiness. The remainder of this chapter is structured into six sections. Section 4.2 contains a description of the Delphi approach used in this thesis. This is followed in Section 4.3. by a description of the preparations made for the Delphi study and highlighting the participants involved in the study. Section 4.4 describes the Delphi rounds, and the results are contained in Section 4.5. The results are discussed in Sections 4.6 and 4.7. The chapter ends in Section 4.8 with a chapter summary.

4.2 Delphi approach in this research

The Delphi approach in this thesis adopts the general approach described in Section 8 contained in Chapter 3. In particular, the Delphi approach in this thesis is based on the following two main stages:

1- During the preparation and setup stage, a group of participants (experts) were approached and selected for the study.
2- Three Delphi rounds were implemented to identify the factors and the dimensions of process innovation deployment readiness in manufacturing. The participants reach a consensus in Round three. In each Delphi round, feedback is provided to the participants, the purpose of which is interaction and reflection.

The stages and the results obtained are presented in this chapter.

4.3 Preparation and Participants

In the preparation stage, the participants are identified, selected, and invited to the study. Participants were from the manufacturing industry and academia. Rules and schedules of the research were developed accordingly. The process of recruiting the experts is initiated by the researcher and involves drafting a list of potential experts from various professional groups, e.g., Conference publications, LinkedIn, ResearchGate, and University websites. The criteria for selecting the participants are 1) Industry: Experience with implementation process innovation with more than three years of experience in manufacturing management or 2) Academia: Involvement with implantation of innovation in manufacturing for at least three years and have publications on the subject area. 3) they must be 18 years old or over.

Fifty-eight people were identified as potential participants in this study, and fifty-eight were contacted by email. Of the total of 58 contacted, 12 responded to the e-mail and agreed to take part in the research, representing a total of 20.68 % response rate.

Table 9 summarises the demographics of the participants. Among the participants, there were people from different job positions, such as researchers, Lecturers/professors, managers, directors and CEO. In total, there were four from academia and eight from the industry. The participants averaged 20.9 years of experience, with a minimum of 7 years and a maximum of 40 years, representing a good balance of experience in the Delphi study.

Table 8: Participant’s demographic.

	Specialist area	**Position**	**Experience**
1	Product development & Manufacturing	Academics	24
2	Manufacturing & advance Industrial processes	Industrial and process innovation consultant	18
3	Manufacturing engineering and management	Managing partner, Chief Consultant & Continues Improvement executive	40
4	Disruptive technologies driving Innovation, Skills in the workplace, in-company learning and their effect on innovation	CPC Business Fellow - Academics	35
5	Manufacturing Business Improvement	Director - Industry	17
6	Senior Academic Manager Enterprise Strategy	Fellow at The RSA (Royal Society for the encouragement of Arts, Manufactures and Commerce) - Academics	40
7	Cleantech Innovation, Systematic Innovation, Biomimetics, Cradle to Cradle®	Research Associate	20

Table continues-next page.

	Assessment, Patent Analysis, Lifecycle Analysis, Techno-Economic Modelling		
8	Production and quality management	Production and quality manager	7
9	Mechanical and Manufacturing engineering and management	Senior manager - Industry	7
10	Manufacturing engineering and management	Senior manager - Industry	20
11	Operations manager	Industry - Manufacturing	15
12	Innovation Consultant	Industry - Manufacturing	8

4.4 The Delphi Rounds

The Delphi rounds in this thesis are highlighted in Table 9 below. The Delphi round was conducted using online questionnaires, as discussed in the methodology chapter, i.e. Chapter 3 of this thesis.

Table 9: Delphi rounds

Round	**Main task**
Round 0 (Preparation phase) Pre Delphi stage (Expert)	Introduction to the Delphi study, Aims and objectives and presentation of the list of attributes and factors obtained from the literature.
Round 1	Summary of the results of round zero and entering them into the questionnaire distributed in the first round. Consolidate Delphi round 0 factors into an initial list of dimensions.
Round 2	Consolidate Delphi round 1 factor and descriptors, and provide feedback from round 1 to the participants. Solicit participants' input to the areas in round 1 for which an agreement has not been reached. Compile results of round 2.
Round 3	Reconcile new/modified factors from round 2 and agree on consolidated factors and descriptors. Analyse the results of all rounds of testing; Report of the Delhi results and an agreed dimension-factor-attributes framework for process innovation deployment readiness in manufacturing.

Feedback report

Feedback report

In the Pre Delphi-stage - Round 0, the main task is an introduction to the Delphi aims and objectives and a presentation of the list from the literature. These are primarily:

1. Climate for Innovation
2. Flexibility

3. Kind of Process Innovation
4. Process Innovation Performance
5. Quality of Deployment plan

The number of participants reduced during the study due to various reasons such as work pressures, family circumstances, change of job, holidays, and moving abroad. There were 12 participants in Round 1 of the Delphi study, i.e. those that agreed to participate from the onset. Eight participants were in the last round of the Delphi study.

Each round takes about two months to complete. The general procedure in each round was to send present the participants with feedback from the previous round, solicit their views on grey areas from the previous round and compile the results of the round.

4.5 Results and analysis

4.5.1 Round One Result and analysis

Based on the Delphi aims and objectives, the initial list of factors from the literature (I- Climate for Innovation, II- Flexibility, III- Kind of Process Innovation, IV- Process Innovation Performance and V- Quality of Deployment plan) were introduced to the participants, and the feedback form participant was collected. The dimensions are based on our review of the literature on factors that influence implementation/deployment readiness in manufacturing. We asked participants to review the proposed dimensions by either modifying the dimensions and/or introducing new dimensions.

A description of the initial set of dimensions for assessing deployment readiness presented to the participants are listed in Table 10 below. For the first round of this Delphi study, we asked participants to review the proposed dimensions and send their feedback within a month.

Table 10: Proposed Dimensions

Table continues-next page.

No.	Dimension	Description
1.	**Quality of deployment plan**	A deployment plan illustrates the approach, scope, and execution plan for the deployment of the innovation initiative. Plans may include a) information on system support, b) roles and responsibilities before, during, and after deployment, c) schedule of deployment activities and d) problem tracking and escalation processes. deployment plans can be formalised (made explicit) or informal (implicit).
2.	**Climate for Innovation**	This is the climate (prevailing conditions) in which the process innovation is taking place. This could include the organisation's support, e.g. in terms of encouraging and respect for creativity, motivation and reward system.

3.	**Flexibility**	Ability to readily adapt to changes and willingness to change or compromise.
4.	**Kind of Process Innovation**	The specific focus of the deployment, e.g. production process focus, technology focus, delivery and supply chain focus, etc., in terms of value/non-value adding activities.
5.	**Process Innovation Performance**	Expectations and constraints on performance.

Participants provided their comments on the questions asked in Round one. A summary of round one responses is presented in Table 11 below. In the table, Yes indicates an agreement that the corresponding dimension applies, no that the dimension does not apply, and partially signifying not a complete vote for a yes. Some of the participants added comments to their vote.

Table 11: Summary of the response of round one

	Quality of Deployment plan	**Climate for Innovation**	**Flexibility**	**Kind of Process Innovation**	**Process Innovation Performance**
Participant 1	Yes	Yes / Comments	Yes	Yes	Yes
Participant 2	Yes	Yes / Comments	Yes	Yes	Yes
Participant 3	No	No	Yes	No	?
Participant 4	Partially	No	Yes	Partially	Partially
Participant 5	Yes	No	Yes	Yes	Yes
Participant 6	Yes	Yes	Yes	Yes	Yes
Participant 7	Yes	Yes	Yes	Yes	Yes
Participant 8	Yes	Yes	No	Yes	Yes
Participant 9	Yes	Yes	No	Yes	Yes
Participant 10	Yes	Yes	Yes	Yes	Yes
Participant 11	No	Yes	Yes	Yes	Yes
Participant 12	Yes	Yes	Yes	Yes	Yes
Yes	9	9	10	10	10
No	2	3	2	1	
Partially	1			1	2
Yes%	75%	75%	83%	83%	83%

The detailed response of round one is as follows. Tables 12 to 16 are the detailed participant response of round one to each dimension.

Dimension 1 - Quality of Deployment plan		
Description:	A deployment plan illustrates the approach, scope, and execution planned for the deployment of the innovation initiative. Plans may include a) information on system support, b) roles and responsibilities before, during, and after deployment, c) schedule of deployment activities, and d) problem tracking and escalation processes. Deployment plans can be formalised (made explicit) or informal (implicit).	
Participant 1	Yes	No Comments
Participant 2	Yes	No Comments
Participant 3	No	Consider splitting Organisational & technology readiness
Participant 4	Partially	Perhaps in the history of the mass manufacturing and production, the level of quality deployment has been a crucial component for any enterprise. This may include various planning stages, including budgetary component. I don't think that any two given enterprise exercise the same level of quality deployment, largely due to the nature of their business and more importantly, the work ethos of the senior management and general working culture.
Participant 5	Yes	No Comments
Participant 6	Yes	Training, Timing. Robust training and Timing plans.
Participant 7	Yes	No Comments
Participant 8	Yes	Add (e) performance measures that will demonstrate the 'improvements' gained by the deployment, e.g. Reduced waste, quicker assembly times, less rework, greater sales…
Participant 9	Yes	Risk & opportunities. What are the potential risks? The quality plan should include potential risk. Risk include quality plan (e.g. limited scope), people, resources availability.
Participant 10	Yes	Include all the resources listed in ISO 56002, including skills available internally and those needed to be contracted or recruited.
Participant 11	No	Metrics to deployment plan - Quantifiable and qualifiable metrics to track, monitor and register plans regarding a) information on system b) roles and responsibilities before, during, and after deployment i.e RASIC, c) schedule of deployment activities, and d) problem tracking and metrics that will flag an escalation process
Participant 12	Yes	Deployment plans should be formalised For successful adaptation in the system

Table 12: Dimension 1 - Quality of deployment plan

Dimension 2 - Climate for Innovation		
Description:	This is the climate (prevailing conditions) in which the process innovation is taking place. This could include organisation's support e.g. in terms of encouraging and respect for creativity, motivation and reward system.	
Participant 1	Yes	How you measure or assess culture in a controllable way.
Participant 2	Yes	Add: Top management leadership ability and style
Participant 3	No	Or, consider moving organisational readiness to this Dimension?
Participant 4	No	Seems unclear as to the requirement. How about (need/requirement /importance for/of innovation . Largely, manufacturing industries, as well as other industrial discipline exercise as per Table 1. How, I would like to add that reward system is of significant importance and that the senior management should recognise the commitment from their employees, who are in actual fact the companies 'assets'.
Participant 5	No	External/internal factors driving change. Circumstances driving innovation could include internal factors (e.g. process improvement) or external factors (e.g. new technological advancements)
Participant 6	Yes	Cost. Cost or quality benefits
Participant 7	Yes	No Comments
Participant 8	Yes	Climate feels more like the conditions just now, e.g. Recent redundancies overwork due to scarce resources, lack of training, high levels of motivation, promotion prospects. There is also culture which I think is bigger than just flexibility that you have as in item 3
Participant 9	Yes	No Comments
Participant 10	Yes	Also include strategy and management in this Description.
Participant 11	Yes	Be very specific on the specific and enabling infrastructure required
Participant 12	Yes	No Comments

Table 13: Dimension 2 - Climate for Innovation

Table 14:Dimension 3 - Flexibility

Dimension 3 - Flexibility		
Description:	Ability to readily adapt to changes, and willingness to change or compromise.	
Participant 1	Yes	No Comments
Participant 2	Yes	No Comments
Participant 3	Yes	But, does this relate to senior staff, managers and employees?
Participant 4	Yes	Manufacturing industries, regardless of the size of the enterprise, will need to be much more flexible, leaner and able to create synergy within the business group as well as create partnership externally.
Participant 5	Yes	No Comments
Participant 6	Yes	No Comments
Participant 7	Yes	No Comments
Participant 8	No	(I would prefer culture) Here I want to amplify what I have said about culture. There is a world of difference between a company that has produced the same product for the same customer over many years and the one that is actively seeking out new markets and customers and endeavouring to grow the diversity of its products. Culture is about whether staff have grown to accept we living in a constantly changing world or they prefer stability.
Participant 9	No	No Comments
Participant 10	Yes	No Comments
Participant 11	Yes	Available time, resources, infrastructure, skillset, training and development time
Participant 12	Yes	No Comments

Dimension 4 - Kind of Process Innovation		
Description:	The specific focus of the deployment, e.g. production process focus, technology focus, delivery and supply chain focus, etc. in terms of value/non-value adding activities.	
Participant 1	Yes	No Comments
Participant 2	Yes	No Comments
Participant 3	No	Isn't this the 'issue under investigation,' which is the title not a dimension. Or, perhaps I have misunderstood it.
Participant 4	Partially	Type of Process Innovation. Process innovation is not always compatible for a given manufacturing industry. This is largely dependent on the nature of the business and also, future business goals. Industry 4.0 will be integrated by enterprises willing to grow and secure given proportion of the market. This can also include the future generation of digital twinning and remote communication devices of the 5G configuration.
Participant 5	Yes	No Comments
Participant 6	Yes	No Comments
Participant 7	Yes	This should not be limited to value add/non-value add. Consideration to be given to whether the innovation is technology-enabled or cultural
Participant 8	Yes	(I would prefer type of process innovation) This must be a two-level view. At the top level is the process that is being deployed. There is a second level that deals with the knock-on effects of that deployment. If the deployment is a technological one, what are the implications for the production activities or even the logistic activities.
Participant 9	Yes	No Comments
Participant 10	Yes	No Comments
Participant 11	Yes	No Comments
Participant 12	Yes	No Comments

Table 15: Dimension 4 - Kind of Process Innovation

Dimension 5 - Process Innovation Performance		
Description:	Ability to readily adapt to changes, and willingness to change or compromise.	
Participant 1	Yes	No Comments
Participant 2	Yes	No Comments
Participant 3	?	Is this 'red/green/amber' from a risk perspective?
Participant 4	Partially	Performance of Innovative Process and possibly product? Perhaps performance of a given innovation is not always easy to measure as there are number of other influencing factors. Although, it is envisaged that the innovation of a given process would tend to lead to improvement. There are number of statistical data which can reflect the same. Traditional improvement tools such as lean manufacturing is a vital component for any manufacturing enterprise as it has shown to improve the performance and reduce the overall cost of a system/process.
Participant 5	Yes	Overcome skills gap. Skills gap greatest factor in innovation performance
Participant 6	Yes	Metrics. Robust metrics to measure success of deployment.
Participant 7	Yes	No Comments
Participant 8	Yes	I think "Expectations and constraints" is a very weak description of what I would expect when looking at performance. I have already mentioned performance measures under item 1. There is the performance of the deployment, e.g. Does it take two weeks or six months to embed a new manufacturing process?
Participant 9	Yes	No Comments
Participant 10	Yes	No Comments
Participant 11	Yes	Need Specific Metrics
Participant 12	Yes	No Comments

Table 16: Dimension 5 - Process Innovation Performance

Additional dimensions recommended by the Delphi participants are listed in Table 17 below.

Additional Dimension Suggested	
Participant 1	**Maturity of the innovation**
Participant 2	**Financial stability:** Whether financial stability is sufficiently robust to enable sustained focus.
Participant 3	No Comments
Participant 4	**Technology:** As the manufacturing industries align their business aims and objectives more towards negating losses, particularly in the environment of global politics and competitiveness, I believe 'technology' is and will continue to play vital role within the manufacturing industry. Predominantly, Industry 4.0 (I4.0) which will also be twinned with the 5th Generation telephonic communications, Advance machine learning algorithms etc. The traditional tools such as ERP/MRP will require re-calibrating and will very likely be replaced with instant, central information sharing capabilities

Participant 5	**Scale-Up / Extend**. How do you take that model and replicate in other parts of the business if successful the first time.
Participant 6	**Lessons Learned.** Post deployment closed loop feedback. Things gone well/wrong, improvements, replication
Participant 7	No Comments
Participant 8	**Purpose of deployment:** The Purpose of the deployment of the innovation initiative must be communicated to all the player affected by the deployment to ensure they commit to the necessary changes. Does the purpose provide economic, ergonomic, organisational and/or customer benefits which will convince staff of the necessity of the deployment
Participant 9	**Change Management:** Management skills to handle changes that will occur due to implementation
Participant 10	No Comments
Participant 11	**Principle of Innovation:** Technical core idea, Scientific finding, Manufacturing advancement et al
Participant 12	**Education** - a) Education employees about the new technology and providing them with enough resources b) Convincing the staff and employees of the required new technology and its necessity through education

Table 17:Additional Dimension Suggested

The comments listed in Table 18 were additional comments received from the respondents in Round one of the Delphi study.

Comments	
Participant 1	No Comments
Participant 2	No Comments
Participant 3	**Observation:** In general, readiness represents the extent to which an implementation has run smoothly and relatively problem free. Organisational readiness generally refers to 'the extent to which organisational members are psychologically and behaviourally prepared to implement organisational change' (Eby et al., 2000) Technology-readiness constructs are 'people's propensity to embrace and use new technologies for accomplishing goals in home life and work' (Parasuraman, 2000). Where are these two key components captured in your Proposed Dimensions? **Question:** You may argue that this will be covered in Stage 2 (weights associated with each dimension), however, central to your approach is knowing 'how to measure the degree of readiness.' The question is, given the multiple components of each Dimension, is your Rubric 'sensitive' enough to discriminate, given that an overall readiness estimate of an organisation is a function of the readiness estimates of the individual influencing factors?
Participant 4	No Comments
Participant 5	No Comments
Participant 6	No Comments
Participant 7	No Comments
Participant 8	No Comments
Participant 9	No Comments
Participant 10	To what extent does the tool take account of BS ISO 56002:2019 Innovation management — Innovation management system — Guidance. All Dimensions (Factors) are relevant and necessary but not necessarily sufficient. Since innovations have a lifecycle, which then relates to them to time, I would order them according to when they are necessary or most

	important. The Climate for Innovation is the starting point, because that governs whether the company is actively interested in innovation and how initial ideas are received, and whether there is a process for encouraging/spotting/identifying and supporting a flow of innovations. Kind of Process Innovation is perhaps next, followed by an extra Factor – Quality of Assessment and Adoption Process. Innovation, whether coming from inside the company or suggested for adoption from external sources, needs to be assessed for value and feasibility. Quality of Deployment plan would be next, then Flexibility and finally Process Innovation Performance. **Recommendation:** Innovation Capability Maturity Model: An Introduction. Darrell Mann, 2012 (book). From www.systematic-innovation.com. The Innovator's Dilemma. Clayton Christensen, 1997, 2016 (book). See in particular the key distinction between 'sustaining' and disruptive innovation and why the latter usually needs to be developed in a spinoff organisation.
Participant 11	No Comments
Participant 12	No Comments

Table 18: Comments

An analysis of the responses from the participants in round one of the Delphi study reveals the following key points.

1) All the proposed dimensions were acceptable to participants, with an acceptance rate of 75% and above (see Table 12). Flexibility, Kind of Process Innovation, and Process Innovation Performance were rated higher in comparison to the Quality of deployment plan and Climate for Innovation.
2) Participants raised some issues regarding clarity, measurability, and the need for specific metrics for some of the dimensions introduced in Round one. In particular, the main areas of concern are the 'Climate for Innovation' dimension, which is said to 'feel more like the conditions just now' and that the dimension comes across as an ambiguous requirement. A related concern is 'Culture', especially how to measure culture in a controllable way. According to a participant, 'culture is about whether staff have grown to accept we are living in a constantly changing world, or they prefer stability. In our definition of 'Climate for Innovation' in Round one, we viewed climate as the prevailing conditions in which the process innovation is taking place; with hindsight, the dimension perhaps is better captioned as part of the context for the process innovation.
3) The issues raised regarding a deployment plan is about clarity regarding what the dimension captures with an emphasis from a participant that the dimension should have 'quantifiable and qualifiable metrics to track, monitor and register plans regarding: a) information on system b) roles and responsibilities before, during, and

after deployment, i.e. RASIC (responsible, approves, supports, is informed, is consulted) matrix, c) schedule of deployment activities, and d) problem tracking and metrics that will flag an escalation'.

4) A participant's view expressed in Round one is that the 'performance of a given innovation is not always easy to measure as there are several other influencing factors. It is suggested that the performance dimension should be expressed in terms of expectations and constraints.
5) The 'Kind of Process Innovation' dimension has significant support from participants. However, there are suggestions that the word 'kind' should be changed to 'type' to make the dimension clearer. Also highlighted is a need to consider the enablers of process innovation, e.g. technology-led, cultural led and the knock-on effects on deployment from supporting services, e.g. supply chain and logistic activities.

After considering all the suggestions and comments, the following commentary was provided to the participants regarding Round one of the Delphi study.

1) The Quality of the deployment plan dimension is generally acceptable. The contents of the deployment plan appear to be a concern, and various suggestions should be contained in the plan. These are that the plan should have various stages, including a budgetary component that should also consider risk and opportunity, including people and resources availability. In addition, there should be the aspect of training and an appropriate activity timing schedule. Also noted, there is a need to include in the deployment plan the performance expectation and how that would be measured. Finally, the plan should also indicate skills and resources available internally and those that are to be contracted or recruited. This should preferably be in the context of ISO 56002.
2) It needs to have organisation and technological readiness dimensions explicit has also been raised, particularly regarding comments on the deployment plan.
3) There is significant support for the climate for the innovation dimension. However, it appears that this dimension can be a little confusing; it has been suggested to make it clearer. For example, it has been suggested that the condition that goes into the notion of climate for innovation needs to be made clearer. Notably, the notion of climate feels more like that the condition just now. The culture,

management, and organizations, including the reward system, are some of the factors mentioned regarding this dimension.

4) Dimension three is flexibility and has significant support from participants. In specifying the flexibility dimension, there will be a need to identify the types of flexibility, e.g. mix, volume regarding product and resourcing, e.g. staff, managers and employees.
5) Dimension four which is a Kind of Process Innovation, has significant support from participants. However, the word kind suggested being changed to type to make the dimension clearer. Also highlighted there is a need to consider the enabled of the process innovation, e.g. technology-led, cultural led and the knock-on effects of that deployment (supply chain and logistic activities).
6) Dimension five that is Process Innovation Performance has significant support from participants. The difficulty expressed regarding this dimension is how the performance needs to be measured and what are the metrics for measuring the performance of deployment. In terms of deployment readiness, should be on performance ex-ante are much better to look at expectations and constraints.

Also considered is a possible consideration of the dimensions of process innovation deployment arising from Round one of the Delphi study. The potential consolidation is shown in Table 19.

Table 19: Additional Suggestions from Participants

Dimensions	Descriptors
Budget & Financial resources	• Budgetary component. • Resources availability, including those listed in ISO 56002. • Reward system. • Financial stability.
External factors	• Supply chain and logistics; stakeholder pressure; customer satisfaction.
Innovation context	• Maturity of the innovation. • Technology readiness. • Specific and enabling infrastructure. • Need/requirement /importance for/of innovation. • The principle of innovation – the technical core idea, scientific finding, manufacturing advancement etc.
Management	• Change Management. • Lessons learnt, knowledge transfer and experience including scale-up/extend.

Table continues-next page.

Organisation & leadership context	• General working culture. • Work ethos of the senior management. • Strategy and management. • Top management leadership ability and style. • Problem tracking and metrics that will flag an escalation process. • Organisational readiness.
Plan and Vision	• Clear timing of events in plans. • Roles and responsibilities before, during, and after deployment, i.e RASIC (responsible, approves, supports, is informed, is consulted) matrix. • The potential risks. • Schedule of deployment activities.
Process innovation performance	• Propensity to achieve performance expectations and demonstrable improvements subject to constraints.
Human Resources	• Human – Training and Education

A problem arising is how to select the right dimensions that are simple and sufficient to capture the necessary metrics. As pointed out by some participants, 'All dimensions are relevant and necessary but not necessarily sufficient, and the 'question is, given the multiple components of each dimension, given that an overall readiness estimate of an organisation is a function of the readiness estimates of the individual influencing factors which dimensions are best qualified to appear on the list. To answer these questions, attention is turned to the pillars of innovation identified in the literature (examples in Table 20 below).

Table 20: Four Examples of Pillars of Innovation Identified in the Literature

I	a) People, b) Culture and climate, c) Structures and processes, and d) Leadership.
II	a) Strategy, b) Innovation sources, c) Innovation capacity, and d) Innovation processes.
III	a) Policy and Vision, b) Infrastructure, d) Fund, and c) Human Capital.
IV	a) Context, b) Culture, c) Capability and d) Collaboration.

Pillar example item IV of Table 20, i.e., context, culture, capability, and Collaboration, was adopted and consolidated with the list of dimensions shown in Table 19. The resulting list of dimensions, associated factors and descriptors is shown in Table 21 below. This consolidated list was presented to the participants in Round two of the Delphi study.

Table 21: Consolidated List of Dimensions, Factors and their Descriptors - 4Cs&P Dimensions

Dimension	Factor	Descriptors
Context	Vision & Plan	• Strength of the evidence for the proposed process innovation deployment - Need/requirement /importance for/of innovation. • Established Roles and responsibilities before, during, and after deployment, i.e. RASIC • Schedule and clear timing of deployment activities. • Potential risks and response strategies. • Investment plan. • Alignment of changes associated with the deployment and business strategy.
	Innovation Context	• The type of process innovation. • Technology readiness is associated with the process innovation. • Specific and enabling infrastructure required for the process innovation deployment. • Knowledge and understanding of the technological context of the process innovation deployment.
	Organisational and Leadership Context	• Organisational members' shared resolve to implement the process innovation (Deployment commitment) • Organisational members' shared belief in their collective capability to do so (Deployment efficacy). • Drive to guide and support the process innovation deployment (Support for the deployment) • Reward system and associated processes that facilitates process innovation deployment (Deployment processes).
	External Factors	• External Stakeholder influences on the process innovation deployment including supply chain, logistics, government, contractors, and customer.

Dimension	Factor	Descriptors
Culture	Prevailing Cultural Norms.	• Clarity of deployment procedures from a cultural perspective. • Alignment of prevailing culture to the process innovation deployment strategy.

Dimension	Factor	Descriptors
Capacity	Budget	• Financial resources availability. • Financial stability.
	Human Resources	• Availability of capable human resources. • Development and stability of human resources including training. • Clarity of role and ownership of the deployment process.

Table continues-next page.

	Technical Resources	• Technical resources availability. • Risk level of technological-resource impediment(s) during the deployment.
	Flexibility	• Flexibility to manage risks and uncertainty.

Dimension	Factor	Descriptors
Collaboration	Project Management	• Appreciation level of project and change management. • Availability of project champion. • Supervision level of the deployment. • Adherence to ground rules. • Issues and problem tracking including metrics that will flag an escalation process. • Transfer of learning and experience.

Dimension	Factor	Descriptors
Performance	Deviation from target.	• Propensity to achieve performance expectations and demonstrable improvements subject to constraints.

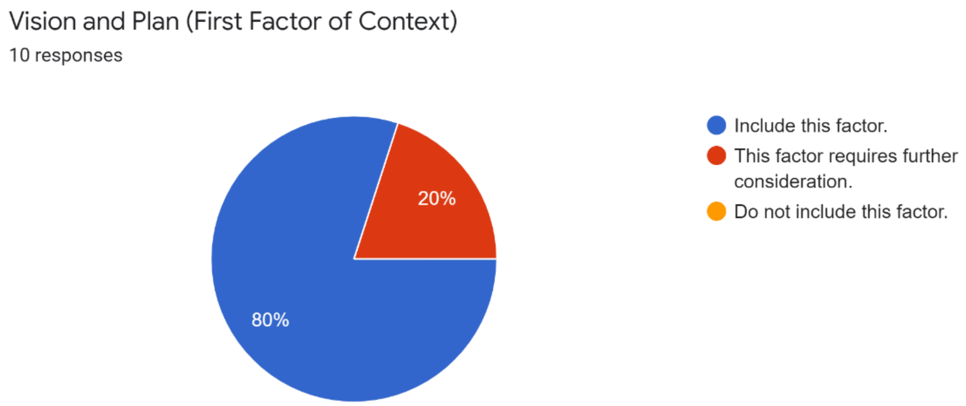
4.5.2 Round two Results and analysis

The focus of round two is the analysis of the feedback provided to participants arising from Round one of the Delphi study. Participants were asked to review the dimensions, factors and descriptors and send their comments to the researcher within a month. Table 22 present the summary of the responses from Round two of the Delphi study.

Table 22: A summary of the responses from Round 2 of the Delphi is as follows.

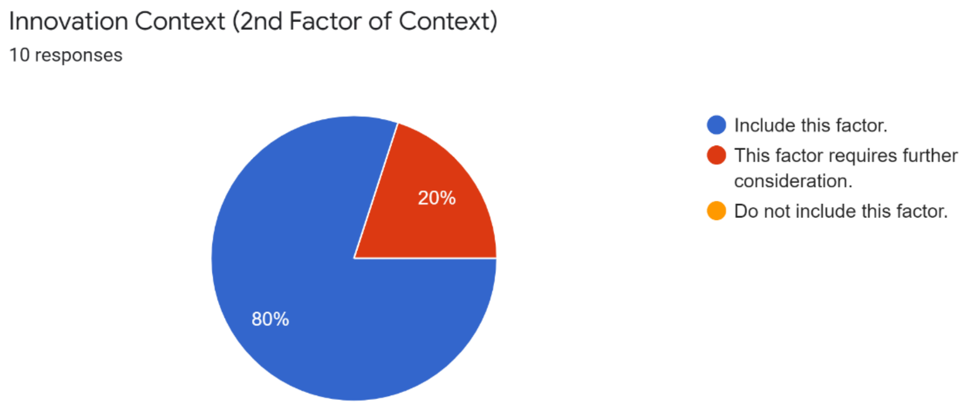
% Responses: Include				
Factor (Majority Accept)	**%**		**Factor (Low Acceptance)**	**%**
Vision and Plan	80		Organisation and leadership context	40
Innovation Context	80		External Factors	20
Prevailing Cultural Norms	60		Flexibility	50
Budget	60			
Human Resources	80			
Technical Resources	80			
Project Management	80			
Deviation from Target	80			

Details of the responses of round two are illustrated as follows. Included in the details are the participants' comments regarding each of the factors.



Comment: (Comments for the above choice)

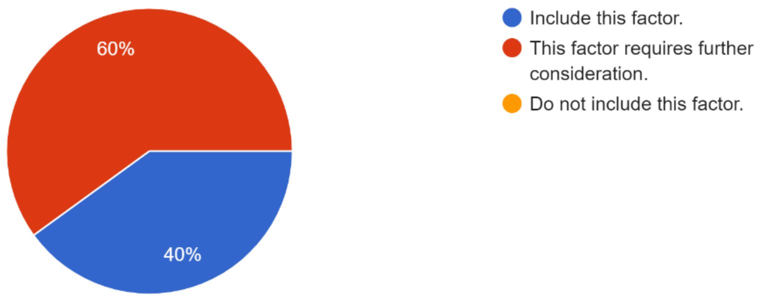
1. You mention RASICS but do you not need to specify what the metrics are for each descriptor. I believe this is a minor consideration before inclusion.
2. Vital 1st Step
3. Consideration should be given to performance measurement against the plan.
4. A Vision and Plan is important for embedding innovation into the company strategy - whatever size the company is.



Comment: (Comments for the above choice)

1. This appears to be self-contained.
2. A process can be innovative for one part, structure or system yet established / routine for another. It maybe industry, infrastructure or place specific.
3. The context for process innovation should also include human factors such as skills of production workers and impact on jobs, as well as the environmental benefits and/or impacts, particularly on energy, materials and water efficiency.

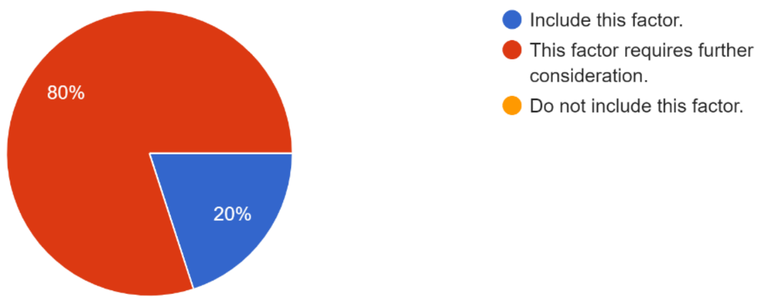
Organisational and Leadership Context (3rd Factor of Context)
10 responses



Comment: (Comments for the above choice)

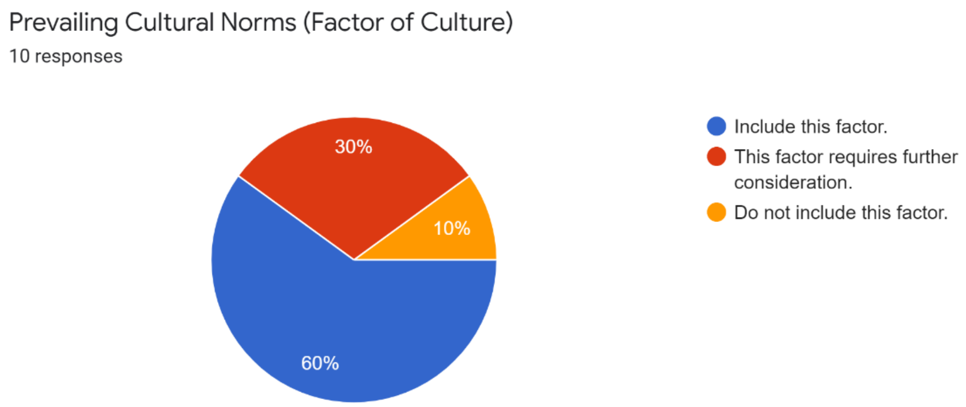
1. Would this not be defined under the Vision and Plan through establishing the roles and responsibilities.
2. As it currently stands, this does not acknowledge the limits of Leadership within the organisation: is there a history of innovations tried & failed (e.g. group think). You may decide that 2nd Dimension - Prevailing Cultural Norms covers this, but I am keen to see that you have included it.
3. See later comments about flexibility.
4. Stakeholder mapping and affiliation / influence or impact to the output. What's in it for them and why. Why they should be motivated to adopt something new.
5. Underlying this factor are human psychology influences, such as personality, cognitive bias, career stage (those nearing retirement more likely to be risk-averse). I don't know if you want to delve into that level. The top level above is okay and can stand alone. (You may wish to look up cognitive biases, of which 188 have been identified; they give good insight into issue with innovation and investment.)

External Factors (4th Factor of Context)
10 responses



Comment: (Comments for the above choice)

1. While this scope requires consideration, how would the requirements for this be gathered, analysed and implemented for each innovation. the scope of external factors needs to be defined
2. It seems odd to see only one Descriptor under this Heading.
3. These factors are important but their relationship to the proposed process innovation and the organisation is not necessarily straightforward. Are you more likely to innovate because your have a particular stakeholder's support or in spite of that stakeholder's reservations.
4. Assuming their are suppliers/contractors implementing the process, how is their responsibility defined, particularly with regard to cost and timing overruns.
5. Selling goods and services or pushing their own . Is it a locking condition because they command and control this process .
6. Unless focused purely on inward influences, include environmental and social impacts. External Stakeholders should include all interested parties.
7. environmental risk assessment can be added
8. No comments.

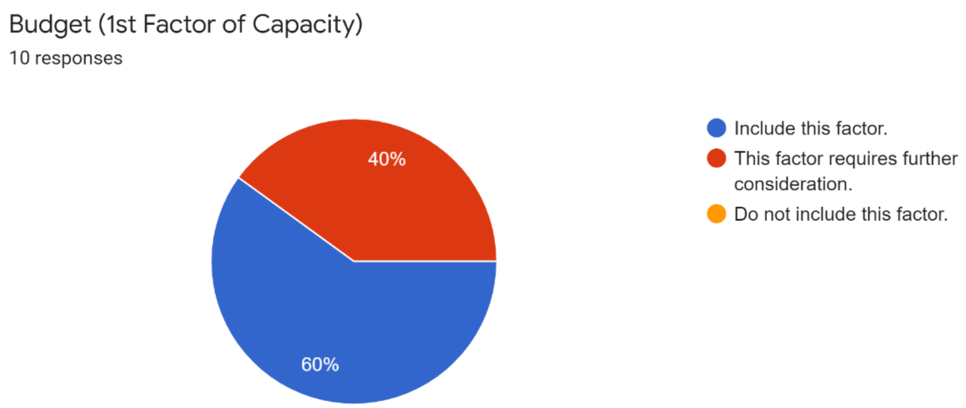


Comment: (Comments for the above choice)

1. My only qtn is, what are your timeframes. 5 yrs, 10yrs. Longer or shorter.
2. As mentioned earlier, precisely because this is an important dimension, it does need a clear definition of what you are referring to as culture.
3. Not entirely sure what this means.
4. Motivation and focus of this culture. New, old experienced, inexperienced . Would this have a greater long term impact . will this be perceived postive or negative .

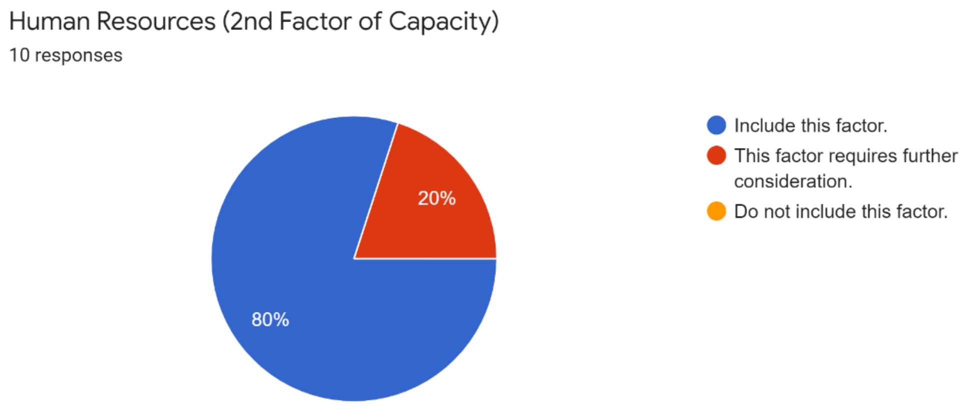
Are they informed enough to resolve own queries and or questions . What is the team dynamics . How hierarchical, competitive or altruistic these can be . Good evaluation will help to change the implementation

5. If not already done, I think you need to define culture quite fully, as it could overlap with the 3rd factor of context. Culture could include unspoken norms which it would be valuable to identify for the purpose of determining any hurdles the innovation may need to clear.



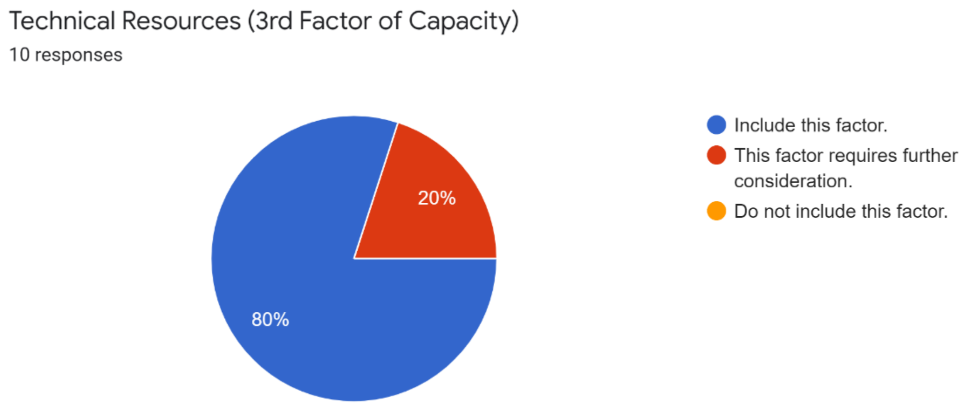
Comment: (Comments for the above choice)

1. Budget issues were described by Hope & Fraser, in a 2003 Harvard Business Review article, “Who Needs Budgets.”, which began, “Budgeting, as most corporations practice it, should be abolished.” A budget often reflects, reinforces and aggravates the organisational structure, which gets in the way of delivering innovative solutions.
2. Essential to gain senior management buy in
3. Is a robust business plan defined. Are the benefits purely financial or other factors - quality, etc. What is the exit plan if these factors are not met. Does the supplier contract clearly define their responsibility in the event expectations are not met.
4. Finance ambitiousness for return on investment. Financial long-term commitment
5. Could also add capacity for financial innovation alongside the technical e.g., use of leasing equipment rather than purchase in order to remove the initial capex barrier.



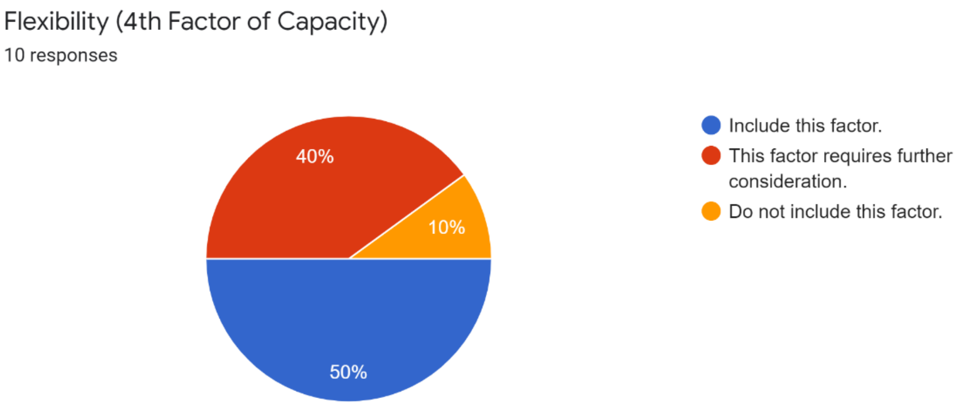
Comment: (Comments for the above choice)

1. I don't know if you have all the Descriptors, but the Dimension needs to be in.
2. Essential to gain senior management buy in
3. Potential impact on employees. Does the process affect employees jobs.
4. Yes, this is good.



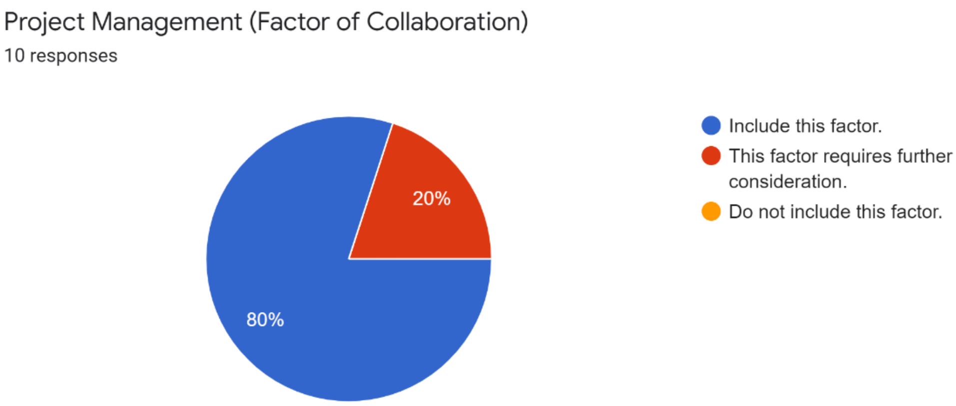
Comment: (Comments for the above choice)

1. Should "Risk levels" be in all or just one Dimension, for consistency. Is it embedded and does not need referring to, in each Dimension. For you to consider.
2. Certainly necessary
3. This factor could be differentiated from 2nd factor of capacity by referring to it as a factor of CAPABILITY
4. Technical competence, adaptability, experience and desire to develop (ambitions)
5. Yes - should make clear that such resources can include those externally available e.g. from relevant consultancies.



Comment: (Comments for the above choice)

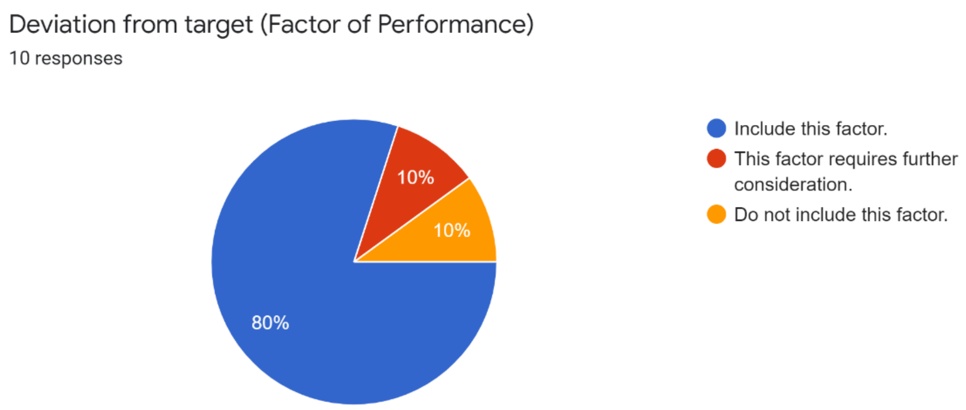
1. See my comments directly above.
2. I can understand what you mean, but I have to ask how this relates to organisational context. You may need to review these two factors (3rd of Context and 4th of Capability) and ensure that they are not overlapping.
3. An element of flexibility is needed, but needs to be closely controlled to avoid targets and aspirations not being met and accepted.
4. Flexibility and adaptability. To change, modify and own new process and it's development.
5. Yes - could also be called agility or adaptive capability.



Comment: (Comments for the above choice)

1. This is for you to decide - Agile vs Prince. Should it have its own Dimension or a given.
2. Co ordination, co operation or collaboration . I appreciate that you mean collaboration in the real field what collaboration means to each and every individual involved .

3. This really includes the whole set of competences involved in professional project management - your list is just a small subset of these. Maybe this factor should involve the acquisition or deployment of professional PM by the innovating company.



Comment: (Comments for the above choice)

1. Achievable goals should be defined from the first dimension and the project manager should be given the metrics to ensure they are on target, unsure if this should be a dimension on its own though
2. I see this as a key 'story telling' Dimension, which describes the journey and provides 'orgnaistional memory.'
3. Here I think of three questions: 1) Can we achieve the required process improvement. Answer Yes/NO. 2) To what degree will the process improvement deliver eh performance changes that were planned. Answer a quantitative metric, e.g. 75%. 3) Will the process improvements be achieved partly or wholly within the planned timescale. Answer a quantitative metric of time. e.g. on time or delayed by x months. performance and delay are both deviations from target.
4. I think this title is a bit odd - should perhaps be Achievement of Target

In addition to the above comments regarding the factors, the participants also provided a general comment that applies to the dimensions, factors and associated descriptors presented to them. The general comments are as follows.

1. I don't believe that I have a lot more to add to the Comments under each Dimension.
2. You have made some interesting progress but you must bring your readers with you. This means having very clear definitions. So although your descriptors make sense, I think you need to use more words to make absolutely sure that your meaning are clear.
3. My general comment is that the criticality of planning is not clearly defined, Business Plan, Timing Plan, Budget, training, contracts, metrics, etc.
4. Think I tried to be specific. Please do not hesitate to contact me if you need further clarification
5. You are probably already doing the following in your study, but I'll mention this in case not: This kind of enquiry should result in a factor analysis, by which key factors are identified statistically from clusters of results arising from empirical observations of activity or from surveys/questionnaires. Doing this enables identification of all critical factors and eliminates the non-critical factors.
6. It's hard to comment on the Dimensions etc because I would really want to see an overall diagram showing how they relate to each other in an innovation process flow. This would also help to identify if anything is missing. This is why I suggested the British/ISO standard and the two books I mentioned. The whole thing needs to hang together. This would give it predictive as well as explanatory power.

An analysis of the responses from the participants in Round two reveals the following.

- We recognise the need to do more work on the three factors that recorded 50% or less acceptance, as shown in table 22.
- The three factors were judged by a majority vote to require further work. We worked on improving the three factors to arrive at a consolidated final list of factors.
- Based on the feedback from round two, we arrived at 12 factors that can be used to assess the deployment readiness of process innovation in manufacturing.

The list of 8 factors and indications of the three others that need revisiting is feedback to participants in Round 3. In addition, to facilitate consensus, a revised list of the factors (taking into consideration all the participants' responses at this stage of the Delphi study) was developed into two tables and presented to the participants in Round 3. The consolidated accepted dimensions, factors and descriptions are shown in Table 23, and the list of new/modified factors which should be agreed upon in round three is shown in Table 24.

4.5.3 Round three, Results and analysis

We have revised the list of factors and descriptors that recorded 50% or less acceptance to accommodate the feedback and research findings. The focus in round three of the Delphi study agrees on a list of modified/new factors and descriptors. To simplify the feedback process, researcher have developed a simple feedback form for participants to complete. Participants had a month to complete and submit the form. Given the feedback from round two, Table 23 shows the list of accepted factors in round 2, and Table 24 shows the list of new/modified factors which should be agreed upon in round three.

Table 23:List of accepted factors in round 2

Factor	Descriptors
1- Vision & Plan	• Strength of the evidence for the proposed process innovation deployment -Need/requirement /importance for/of innovation. • Established Roles and responsibilities before, during, and after deployment. • Schedule and clear timing of deployment activities. • Potential risks and response strategies. • Investment plan. • Alignment of changes associated with the deployment and business strategy.
Factor	**Descriptors**
2- Innovation Context	• The type of process innovation. • Technology readiness associated with the process innovation. • Specific and enabling infrastructure required for the process innovation deployment. • Knowledge and understanding of the technological context of the process innovation deployment. • Prior experience associated with the process innovation
Factor	**Descriptors**
3- Prevailing Cultural Norms.	• Clarity of deployment procedures from a cultural perspective. • Alignment of prevailing culture to the process innovation deployment strategy.
Factor	**Descriptors**
4- Financials	• Financial resources availability.

Table continues-next page.

	• Financial stability.
Factor	**Descriptors**
5- Human Resources	• Human resources availability. • Clarity of roles and responsibilities for the deployment. • Ownership of the deployment process. • Development and training of human resources. • Stability of human resources during the deployment.
Factor	**Descriptors**
6- Technical Resources	• Technical resources availability. • Technological-resource impediment(s) during the deployment.
Factor	**Descriptors**
7- Project Management	• Appreciation level of project management. • Availability of project champion. • Supervision level of the deployment. • Adherence to ground rules. • Issues and problem tracking including metrics that will flag an escalation process.
Factor	**Descriptors**
8- Performance Expectations	• Appropriateness of the target set e.g. high, medium or low. • Propensity to achieve performance expectations and demonstrable improvements subject to constraints.

The tasks in Round three are to review and provide recommendations for four modified/new factors arising from the results of Round 2, Organisational and Leadership Context, External Factors, Deployment Process Visibility, and Adaptive Capability, shown in Table 24 below.

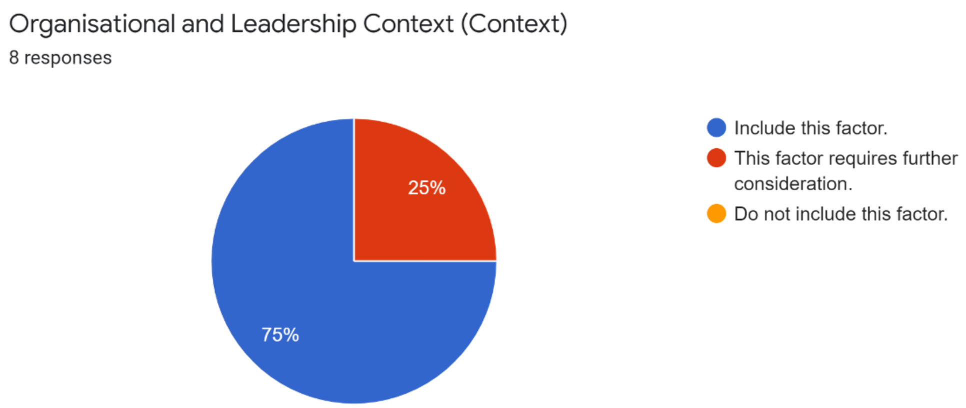
Table 24: List of new/modified factors which should be agreed upon in round three with results.

Factor	Descriptors
9- Organisational and Leadership Context	• Organisational members' shared resolve to implement the process innovation (Deployment commitment) • Organisational members' shared belief in their collective capability to do so (Deployment efficacy). • Drive to guide and support the process innovation deployment (Support for the deployment) • Reward system and associated processes that facilitates process innovation deployment (Deployment processes). • There are organisation compatibility/working practices between members.
10- External Factors	• Influence of government support, policies and regulations. • Influence of competitor's pressure and market forces. • Influence of business environment of supporting industries. • Impact of environmental and social uncertainty.

Table continues-next page.

	• Suppliers and contractor's willingness and readiness to participate.
11- Deployment Process Visibility	• Ability to accurately and completely view other associated activities. • Ability to accurately and completely view the processes. • Ability to accurately and completely view the transaction. • Access to appropriate information technology. • Access to real time information. • Support for information sharing share information.
12- Adaptive Capability	• Ability to continuously gather relevant information, dynamically examine, and use the information to make informed decision (Horizon Scanning). • Ability to make necessary amendments to objectives, plans, structures, and governance systems relating to the deployment (Change Management). • Ability to endure disruptions of all types (Resilience).

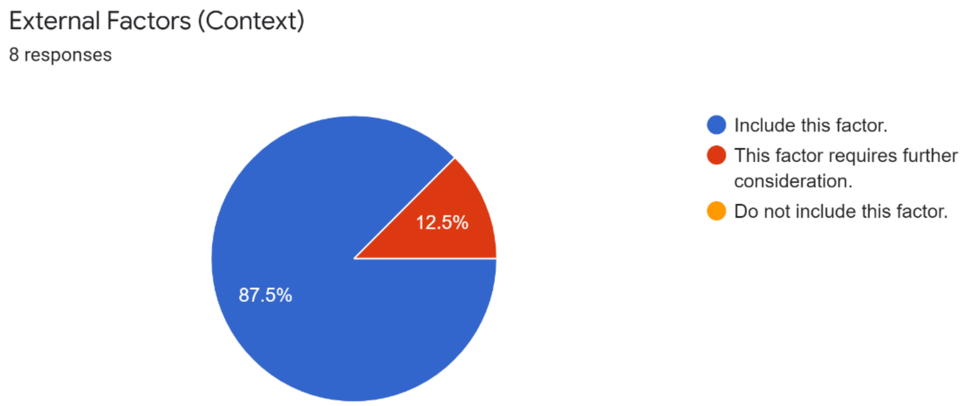
As mentioned above, the results of Round 3 indicate that all of the eight factors in Table 23 were agreed to by all the participants. The results regarding the four modified/new, additional factors in Table 24 are as follows.



Comment: (Comments for the above choice)

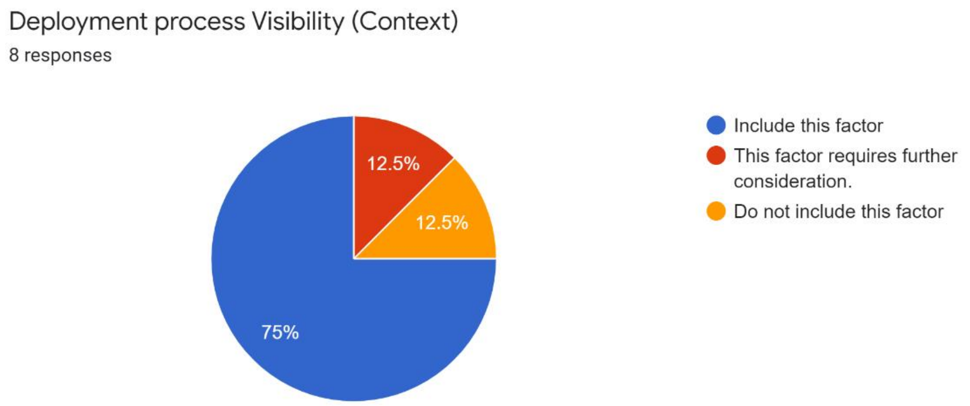
1. Fourth Bullet: revise to start with "Reward system or incentives...". The rewards may not necessarily need to be financial. So using a wider definition will help.
2. Fifth Bullet: I think i know what you mean, but the phrasing is a little vague.
3. Nothing further to add
4. No innovation and its implementation is complete without the buy in of the organisation leaders
5. I would ask you to consider whether a 'reward system' is needed here.

6. Not reflected in the other factors. Necessary for effective innovation or for understanding failures. Last bullet doesn't really make sense - do you mean issues. Express positively, like the other descriptors.
7. Leadership commitment is essential



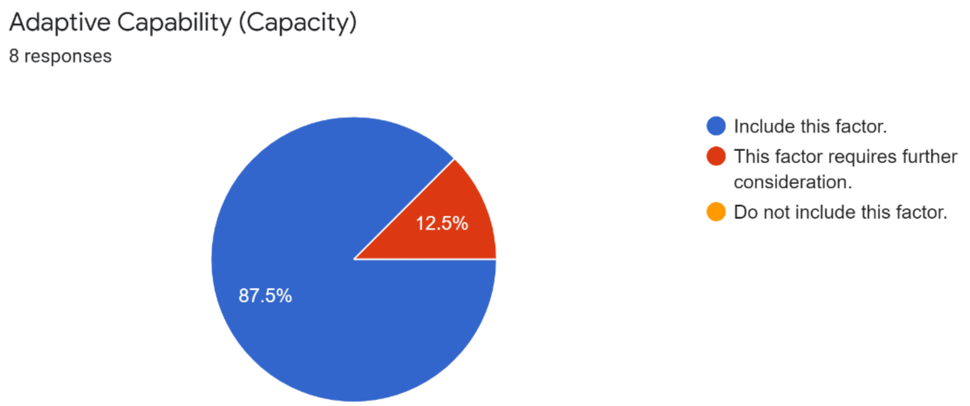
Comment: (Comments for the above choice)

1. Nothing further to add
2. some of the descriptors are not relevant - competitor's influence and market forces may not always impact innovation
3. Useful to know what is driving the factors.
4. Not reflected in the other factors. Add taxation to first bullet. Second bullet should be "Competitor pressure ...". (Could refer to Michael Porter's 5 Forces.) Add 'Influence of customer attitudes and behaviours'; I'm thinking of things like brand loyalty, environmental sensitivity/awareness, which can change dramatically e.g. with plastics, and how large niche higher margin markets are. Last bullet - "contractor's" should be "contractors' ".
5. This factor brings in the involvement of the supply chain, especially



Comment: (comments for the above choice)

1. Last bullet needs an edit. Otherwise this is good.
2. Nothing further to add
3. Looks okay.
4. If by "Deployment" you mean deployment of the innovation process i.e. the R&D starts then yes, this is a valid factor and the descriptors are right. If you mean deployment of the actual innovation into production, then I think this factor is less strong. The last bullet doesn't really make sense.
5. This provide the emphasis on a data-driven approach



Comment: (comments for the above choice)

1. Just one comment. Any organisation may be able to make amendments, but the ones that are good are those that make those amendments in a controlled but efficient way. So rather than use brackets, I would finish the second descriptor with "deployment through an appropriate Change Management Process".
2. Nothing further to add

3. Looks okay.
4. Yes, this is missing from all the above factors and is essential for successful innovation. First bullet: this is not confined to Horizon Scanning, so I suggest delete that reference. Last bullet: add "... and adapt successfully." Disruptions usually require adaptations.
5. Change management emphasis is appropriate

The following general comments were received from the participants in Round 3.

1. I have no further comments. I'm sorry that I can't provide anecdotal evidence from my experience of the validity of these factors - it would take too long to trawl through my experience.
2. Generally, a very good approach

Round three of the Delphi study aimed to agree on a list of modified/new factors and descriptors. Participants were asked to review the factors and descriptors and send their comments to the researcher. Table 25 summarises the responses from Round three of the Delphi study.

Table 25: A summary of the responses from Round 3 of the Delphi.

% Responses: Include	
Factor	**%**
Organisation and leadership context	75
External Factors	87.5
Deployment Process Visibility	75
Adaptive Capability	87.5

Based on the participant's feedback and comments from round three, apart from the 12 factors which were accepted, four more factors were added to the accepted factors, which were finally agreeable to the participants. This recommendation of 16 factors by the Delphi percipients is accepted and used subsequently in the thesis. A revised consolidated list of Dimensions, Factors, and Descriptors is shown in Table 26 below.

Table 26: Round three agrees to consolidate the list of factors and the Descriptors

Dimension	Factor	Description
Context	Vision and Strategic Plan	The vision outlines what the organisation is likely to ultimately achieve with the process innovation and gives purpose to the existence of the organization, presenting an anchor point for the strategic plan.
	Innovation Context	Innovation context is the set of circumstances, including intangible resources, that form the setting for the process of innovation in terms of which its deployment can be fully understood. Emphasis includes the type of process innovation, associated technology readiness level, specific and enabling infrastructure, prior experience, and knowledge and understanding of the technological context required for the process innovation deployment.
	Organisational and Leadership Context	Organisational context is the 'background' or 'environment' or 'atmosphere' in which the organization operates, and within which the deployment is going to take place. It is basically a way of thinking about organisational culture, and motivating individuals within the group to successfully carry out process innovation deployment. The fundamental responsibility of leadership is consciously creating and sustaining Organisational context. Essentially, with organisational and leadership context there is a: a) Organisational members' shared resolve to implement the process innovation (Deployment commitment), b) Organisational members' shared belief in their collective capability to do so (Deployment efficacy), c) Drive to guide and support the process innovation deployment (Support for the deployment), d) Reward system and associated processes that facilitate process innovation deployment (Deployment processes) and e) There are organisation compatibility/working practices between members.
	External Factors	These are factors outside the organisation at both the micro-level (customers, suppliers, and the industry) and the macro-level (national and international context) that influence the deployment of process innovation. The factors include the influence of government support, policies and regulations, b) competitor's pressure and market forces, c) suppliers and contractors and their cooperation, d) national and international business environment of supporting industries, and e) environmental and social uncertainty.

Table continues-next page.

	Prevailing Cultural Norms	Prevailing cultural norms are the currently agreed-upon expectations, standards, and rules by which a culture guides the behaviour of the deployment team.

Dimension	Factor	Description
Performance	Performance Expectations	Performance expectations are requirements of the deployment team including expected outcomes, behaviour and actions. Important is the appropriateness of the target outcome agreed in delivering the implementation with demonstrable improvements subject to constraints.

Dimension	Factor	Description
Capability& Capacity	Dynamic Capability	Dynamic capabilities are the firm's ability to assimilate, develop, integrate and reconfigure internal competencies to appropriately fit the changing environment.
	Absorptive Capacity	Absorptive capacity is the deployment team's ability to identify, assimilate, transform, and use valuable external knowledge toward achieving successful implementation.

Dimension	Factor	Description
Resources	Financial Resources	Finances and financial resource requirements including it is availability, adequacy and stability throughout the deployment.
	Human Resources	Human resources are the set of people who makes up the workforce for the deployment. Emphasis is on availability, clarity of roles and responsibilities for the deployment, development and training, and stability of human resources during the deployment.
	Technical Resources	Technical resources represent the availability of all the physical and non-physical technical assets that are required to support the deployment.

Table continues-next page.

Dimension	Factor	Description
Collaboration	Deployment plan	Is the deployment project plan including a set of controls within project constraints particularly relating to time, cost, scope and quality.

	Deployment Control	Deployment controls are the application of processes to measure project performance against the project plan, to enable variances to be identified and corrected, so that project objectives are achieved. It is aimed at keeping a deployment on track by minimising the gap between the deployment plan and deployment execution to achieve the implementation objective subject to deployment constraints. Essentially, this includes: a) Appreciation level of project management. b) Availability of project champion. c) Supervision level of the deployment. d) Adherence to ground rules. e) Assurances for the control stages
	Deployment Coordination	Deployment Coordination involves managing the day-to-day operations of the deployment, ensuring awareness of deadlines and tasks the deployment team and individuals are responsible for.
	Flexibility	The deployment team is open to different ways of organising resources for accomplishing the target implementation.
	Process Visibility	Process visibility is the ability to see end to end and understand all aspects of the deployment at any point in time.

4.6 Final Outcome and Discussion

The attribute of process innovation deployment readiness found in the literature as contained in Chapter two can be consolidated with dimensions and factors arrived at by the participants of the Delphi study. The consolidated final outcome is referred to in this thesis as a Manufacturing Process Innovation - Dimensions, Factors and Attributes Model (MPI-DFAM). The MPI-DFAM is shown in Table 27 below. The attributes are matched to factors, dimensions and descriptions by a group of five people selected from the Delphi study participants.

Table 27: Conceptual model for Innovation deployment readiness measurement

Dimensions	Factors	Attributes
Context	**Vision and Strategic Plan**	Alignment of innovation strategy to mission, goals and business strategy
		Process innovation implementation vision
		Strategy and Strategic Alignment, Link to customer and business strategy.
		Clarity of Expectation and Constraints
		Standardize procedures for deployment.
		Ability to communicate vision and mission
	Innovation Context	The maturity level of the innovation
		Knowledge and understanding of the new processes and their workflow.
		Protection of innovation
		Specific and enabling infrastructure
	Organisational and Leadership Context	Organisational members' shared resolve to implement the process innovation (Deployment commitment),
		Organisational members' shared belief in their collective capability to do so (Deployment efficacy),
		Drive to guide and support the process innovation deployment (Support for the deployment),
		Ability to handle staff with poor performance.
		Organisational process maturity
		Resilient and able to deal with frustration.
		Organization Structure, Capability, Barrier
		Acquired leadership abilities, Understand and support, Management and Leadership
		Willing to assess and accept changes.
		Reward system and associated processes that facilitate process innovation deployment (Deployment processes) and
		There are organisation compatibility/working practices between members.
	External Factors	environmental and social uncertainty
		suppliers and contractors and their cooperation
		Availability of external support services
		national and international business environment of supporting industries
		Government support, policies and regulations, and Legal environment.
		competitor's pressure and market forces
	Prevailing Cultural Norms	The organization opens to new ideas (encourage innovation)
		Ability to influence cultural readiness for change.
		Knowledge-sharing culture.

Table continues-next page.

Performance	**Performance Expectations**	Clarity about expected behaviour and actions
		Appropriateness of the target outcome
		Aggressive about setting up targets and achieving them.
		Reliable tools to measure and a Valid measurement system
		Justification of process owners, responsibilities, authority, and process performance targets.
		Establish a comprehensive measurement mechanism for the process innovation performance
		Performance measures and expected outcomes are identified, defined, and developed.
Capability& Capacity	**Dynamic Capability**	The appropriate level of internal competencies needed for deployment
		the appropriate level of external competencies needed for deployment
	Absorptive Capacity	Deployment team's ability to identify and use valuable external knowledge towards achieving successful implementation.
		Acquisition capacity
		Assimilation capacity
		Transformation capacity
		Application (or exploitation) capacity
Resources	**Financial Resources**	Availability, adequacy, and stability of Financial Resources throughout the deployment.
		Schedule Scope Budget
	Human Resources	Training (Education Requirements and Policies), coaching and learning opportunities, Training & education at all levels in the organisation, including technical skills development
		The organization encourages process ownership.
		Employees feel free to report information on errors and defects.
		Employees are motivated to self-enhance and adopt a learning culture, and educate on process capability indicators
		Commitment to deployment and Assign Responsibilities
		The organization promotes the involvement of all its employees in quality and CI.
		Motivation, HR system and Human Capability
		Experience, selecting the right people
		Attitudes - Habits
		Skill, Employees' knowledge, and skills
	Technical Resources	Availability of enabling technologies and Infrastructure
		IT Partnership, Subcontractor engagement
		Data Source, Data Management and Data and Information Quality.
		Analytics Capability and Basic consideration of IT usage.

Table continues-next page.

Collaboration	**Deployment plan**	Availability of development plan
		Controls within project constraints relating to time.
		Controls within project constraints relating to cost.
		The overall quality of a deployment plan
		Controls within project constraints relating to scope.
		Controls within project constraints relating to quality.
	Deployment Control	Appreciation level of project management.
		Availability of project champion.
		Supervision level of the deployment.
		Adherence to ground rules.
		Proactive quality system.
		Communications tools implementation
		Assurances for the control stages
		Project management skills and G decision making.
	Deployment Coordination	Managing the day-to-day operations of the deployment
		Ensuring awareness of deadlines and tasks the deployment team is responsible
	Flexibility	flexibility to accommodate changes.
		ability to manage uncertainty
	Process Visibility	Ability to see end to end and understand all aspects of the deployment at any point in time.
		Having appropriate platform, linkages, and support for information sharing

4.7 Discussion of Results

Table 26 shows the consolidated factors obtained from the expert panel. The sixteen factors cover important aspects of process innovation deployment, including resources and performance expectations. The context of deployment matters because there are significant contextual factors that must be taken into consideration. Deployment context is the circumstances that form the setting for the process innovation deployment, expressed in terms of which the process innovation implementation can be fully understood. In the MPI deployment, the external factors, innovation context, organisational and leadership context and prevailing cultural norms are considered key aspects of the deployment context. Organisational context is the background or environment, or atmosphere in which the organization operates and within which the deployment is going to take place. It is a way of thinking about organisational culture and motivating individuals within the group to successfully carry out process innovation deployment. The fundamental responsibility of leadership is consciously creating and sustaining organisational context. Prevailing cultural norms are the currently agreed-upon expectations, standards, and rules by which a culture guides the behaviour of the deployment team. External factors are outside the organisation at both the micro-level (e.g. Customers, suppliers, and the industry) and the macro-level (national and international context) that influence the deployment of process innovation. The factors include a) the influence of government support, policies and regulations, b) competitor pressure and market forces, c) suppliers and contractors and their cooperation, d) national and international business environment of supporting industries, and e) environmental and social uncertainty. The people factor is important in preparing for process innovation deployment in manufacturing.

The result can be discussed within the setting of a context, people, process and technology viewpoint. The people factor is particularly important because the knowledge and skills of the personnel involved in preparing for deployment will help in the planning, control, and coordination of the deployment. So also, is in consideration for the vision and strategy of the company regarding process innovation. When running an MPI deployment project, the need to collaborate with various stakeholders is important as it would involve people handling the key functions of control and planning for adequate process visibility.

An effective deployment plan and control can improve the company's strategy, which would be employed during the design phase or when exploring lower-cost design options. The people factor can also influence deployment capacity and capability. For effective collaboration, finding people with the necessary skills and attitude is a necessary step in implementing an MPI deployment plan and controls. This would involve having the required amount of information which would help in making sure that the changes that may arise due to the plan and control are planned for and making the necessary adjustments accomplishable. The people factor transcends industrial sectors and readiness concepts. The deployment itself is a process which will be influenced by the flexibility with which the deployment can be done and the ability to see the deployment process end to end, i.e. process visibility. Process visibility can be significantly facilitated through information sharing and technology. Technology impact deployment readiness in several ways, principally the technological infrastructure and resources that are relevant to the implementation process. Technical resources are central to deployment readiness, and the technical resources will enable information sharing, among others.

The experts consulted in this study found absorptive capacity relevant to MPI, as evidenced in the process innovation literature in general. Absorptive capacity is 'the firm's ability to recognize the value of new, external information, assimilate and apply it to reach the organization's goals' (Cohen & Levinthal, 1990). To leverage new knowledge obtained from external knowledge sources, internal processes and routines that will facilitate the assimilation, transformation, and exploitation of the new knowledge in the quest for successful process innovation are important (Zahra and George, 2002). Potential absorptive capacity, encompassing a firm's capability to acquire and assimilate external knowledge, is known to mediate the relationship between external knowledge search and process innovation (Aliasghar, Rose, & Chetty, 2019).

Since any organization has its unique specific Dimensions, Factors and Attributes, which can affect its ability to adopt and implement innovation, innovation adopters need to assess an organization's readiness to apply innovation, even if the innovation has already been applied in another company by leading innovators.

Assessing deployment readiness for a company to implement innovation involves evaluating factors such as the Vision and Strategic Plan, Innovation Context, Organisational and Leadership Context, External Factors, Prevailing Cultural Norms, Performance Expectations, Dynamic Capability, Absorptive Capacity, Financial Resources, Human Resources, Technical Resources, Deployment plan, Deployment Control, Deployment Coordination, Flexibility, Process Visibility.

It is important to assess deployment readiness as it identifies any possible difficulties in implementing the innovation and makes the innovation deployment smooth and relatively problem free. Companies may have a different, some encourage change, or some are resistant to change which could make it challenging to implement an innovation. By assessing the innovation deployment readiness even for innovation adopters and understanding their unique factors, such as culture, companies can improve and create a more comprehensive plan and improve innovative culture or obtain the necessary resources or build the necessary capabilities before introducing any innovation.

This will help ensure companies are prepared to implement the innovation successfully and identify any risk that may need to be mitigated.

4.8 Chapter Summary

This chapter, Chapter 4, contains a Delphi study that identifies dimensions of deployment process innovation in manufacturing. The study successfully obtained a consensus on the dimensions and factors of deployment process innovation in manufacturing. According to the participants of the Delphi study, sixteen factors under five dimensions were identified. These results led to the development of a Manufacturing Process Innovation - Dimensions, Factors and Attributes Model (MPI-DFAM), which will be used later in this thesis. The MPI-DFAM will be used to develop a fuzzy approach for accessing manufacturing process innovation deployment readiness in Chapter 6.

5 Conceptual Framework and Evaluation

5.1 Introduction

Over the last few years, researchers and practitioners in manufacturing have increased interest in gaining knowledge and understanding of the effect of process implementation factors on deployment readiness. They believe that innovation is necessary for productivity growth, survival, and competitiveness of a firm, which could improve the company's profit, is not in doubt (Chesbrough, 2003; Cefis and Marsili, 2006; Gonçalves Silveira Fiates et al., 2010). However, the influence of key factors on readiness to deploy process innovation in manufacturing is less clear. Process innovations can be implemented with varying approaches to deployment and with varying degrees of success. Hence, it is essential to consider possible determinants of successful implementation. Several studies have proposed typologies to analyse these determinants (Alavi & Joachimsthaler, 1992; Fullan & Pomfret, 1977; Kwon & Zmud, 1987; Majchrzak et al., 1986; Mankin et al., 1985). However, due to the diversity of contexts and perspectives in implementation studies, this thesis considers it essential to focus on the concepts most relevant to process innovation, as reinforced for innovation in general by Meyers et al. (1999).

This chapter presents a conceptual framework for manufacturing process innovation deployment readiness and uses data from a questionnaire survey to evaluate the framework. An important salient aspect of this chapter relates to preparedness as a construct for process innovation deployment readiness. Other constructs examined are aspects of manufacturing flexibility, deployment plan and climate for innovation. The constructs were selected based on the findings from the literature review reported in Chapter 2 of this thesis and exploratory consultation with manufacturing industry experts experienced in process innovation, including experience of the Delphi study reported in Chapter 4. The rest of this chapter is structured into three main sections. The conceptual framework and hypothesis are presented in Section 5.2. This is followed in Section 5.3 by describing the hypothesis tests carried out, including information about the survey instrument used and sampling and data collection methods. The results of the hypothesis testing are presented in Section 5.4 and discussed in Section 5.5. The chapter ends with concluding remarks in Section 5.6.

5.2 Conceptual Framework and hypothesis

This section is in two parts, namely presentation of the conceptual framework in Section 5.2.1 and contained in Section 5.2.2 is the development of the research hypothesis studied in this thesis arising from the conceptual framework.

5.2.1 Conceptual Framework

In this research, consideration is given to the important constructs that can influence achieving a full readiness state in the deployment of process innovation in manufacturing. Deployment readiness is a vital element in the achievement of innovation implementation. This entails, amongst others, a vision for an innovation idea at the onset, adopting realistic-looking implementation stages intricate to realising the vision, ensuring appropriate staff involvement, and serving them to know in what way(s) the company's chosen approach to innovation might influence the team, in other words providing the climate necessary for deploying the innovation. (Radnor et al., 2006; Al-Najem, 2014).

This thesis opines that for a manufacturing company to be fully ready to deploy its innovation initiative, there should be a right climate for innovation in the company, a deployment plan should be in place, manufacturing flexibility where available should be exploited, and the company should have been prepared for the deployment. The conceptual framework shown in Figure 18 explores this thinking further.

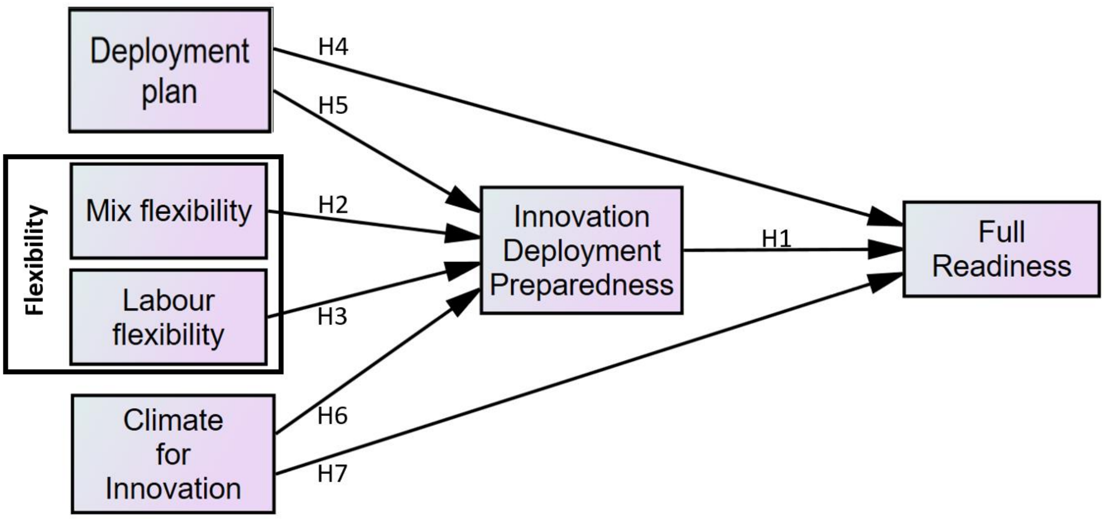


Figure 18:The research model. (H: Hypothesis).

5.2.2 Research Hypothesis

5.2.2.1 Preparedness and Full Readiness

Getting prepared to deploy is an important step when implementing manufacturing process innovation. Preparedness in the context of manufacturing process innovation is conceptualised in this thesis as a state of deployment readiness. To better understand the preparedness and full readiness, deployment readiness is explained further. As previously highlighted, deployment readiness can be visualised retrospectively as the extent to which deployment has run smoothly and relatively problem-free (Ahmadi et al., 2015), and it is an important issue in the pre-implementation phase of innovation implementation models (Papinniemi, 1999; Kwahk and Lee, 2008). For deployment to run smoothly and relatively problem free, it is expected that some preparatory work would have taken place.

The term preparedness has been extensively used in relation to defence and natural hazards. The wider use of this term in this thesis is deliberate and attempts to focus policy thinking on the far more extensive aspects of how science helps us to deal with uncertainty and risk. Essentially, to successfully deploy innovation, there is a need to be prepared. Manufacturing companies operate at different levels of preparedness when implementing innovation, and this can potentially account for some of the variations in the success with which process innovation is achieved in the companies.

The implementation of innovation in a manufacturing organisation is a dynamic and continuous process. However, prior to implementation, organisations are tasked with overcoming different challenges that may occur during the implementation. Hence, it is necessary for an organisation to address the challenges as part of its preparation for deployment and aim for full readiness to deploy over time. Being fully ready for process innovation deployment is typically not a one-time strategy but is a continuous process. It is seldom either a discrete or one-time event; it is an overlapping activity that occurs throughout the life cycle of the organisation. Central to the lifecycle is preparation in the journey to being fully ready to deploy process innovation. It can therefore be hypothesised that preparedness improves getting to a state of full readiness to deploy. Therefore, the following hypothesis, H1, is proposed.

> H1: Preparedness positively influences the attainment of full process innovation deployment readiness.

5.2.2.2 Flexibility and Preparedness

The concept of manufacturing flexibility has become a standard for many manufacturing companies in their stance to be competitive. Manufacturing flexibility is defined as the capability of the company to respond and manage any changes in a manufacturing environment (Mandelbaum, 1978; Gupta Z and Somers, 1992). Along with cost, quality and dependability, flexibility is seen as a competitive priority for manufacturing (Hill, 1994; Hill and Chambers, 1991). There has been tremendous pressure on firms to understand the role of flexibility in terms of a competitive weapon both at the operational level or machine level and in a more strategic or plant level sense (Bower and Hout, 1988; Swamidass, 1988; Swamidass and Newell, 1987). While many authors recognise the importance of flexibility to manufacturing strategy (Hill and Chambers, 1991; Ramasesh and Jayakumar, 1991), firms have had trouble applying the concept to their operations. One problem in understanding flexibility may be the many dimensions by which it can be defined and the various ways in which it can be applied. Over 20 dimensions have been identified in the literature (Swamidass, 1988). Flexibility has also been viewed in a hierarchical fashion, including such levels as a machine, manufacturing systems and aggregate flexibility (Gerwin, 1993). Understanding flexibility has also been hampered, and there is a need for more research on operationalising and measuring flexibility.

Flexibility is a key factor for innovation (Bolwijn and Kumpe,1990). A link between manufacturing flexibility and innovation has been established in previous studies (e.g. Nemetz and Fry, 1988; Bolwijn and Kumpe, 1990; Duguay et al., 1997; Camisón and Villar-López, 2010). Bolwijn and Kumpe (1990) noted that flexibility is a required component of innovation. Nemetz and Fry (1988) explained that manufacturing companies that are flexible should give greater weight to process Innovation as their principal "distinctive competence" for gaining competitive advantage, as in the case of product innovation. This thesis explores two types of manufacturing flexibility in relation to process innovation – Labour flexibility and Mix flexibility.

Labour flexibility

A viewpoint put forward by Duguay et al. (1997) states that manufacturing flexibility may simply be accomplished when the company has both a flexible workforce as well as equipped with versatile machinery. This would then facilitate the quick adaptation to any variations within all aspects of manufacturing processes (Camisón and Villar-López 2010). With such competencies, manufacturing companies should be able to leverage a flexible workforce to prepare to deploy their process innovation initiative and journey through full readiness to deploy the initiative.

Increasingly, teamwork with a flexible workforce is seen as a new way to organise work in an innovative organisation which can help to empower employees and shift decision-making control to the people actually performing the task (Levi and Slem, 1995). A team working on deploying innovation can perform any type of operation successfully. Usually, Cross-skilled employees can operate a broad range of manufacturing tasks efficiently in the organisation. The capacity to operate in different types of jobs and work with different machines, which characterises labour flexibility, can help support process innovation deployment readiness. It could help the employee to move between different units more easily when required.

Labour flexibility is 'the ability of the personnel to carry out a different type of manufacturing duties efficiently and effectively' (Zhang et al., 2003). Cross-training or multi-skilling is the main source of labour flexibility (Oke, 2005). As Zhang et al. (2003) noted, the personnel are an important part of innovation deployment (Hyun and Ahn, 1992, Ramasesh and Jayakumar, 1991, Upton, 1995, Jack and Raturi, 2002). There are evidenced performance consequences of flexibility (Swamidass and Newell, 1987, Pagell and Krause, 2004, De Meyer et al., 1989), including labour flexibility. As with other flexibility types, labour flexibility can be a strategic tool to compete and useful in attaining readiness to deploy process innovation. Labour flexibility is known to be multi-dimensional in nature (e.g. Oke, 2005, Hyun and Ahn, 1992, Brown et al., 1984, Slack, 1987, Suarez et al., 1996, Koste et al., 2004). It is argued that having labour flexibility in manufacturing companies permits labour resources to carry out a range of duties because they are cross-trained. Cross-trained workers may be able to provide new ideas and deal with problems when they prepare for deployment by utilising and tapping from the varieties of skills that they possess. Therefore, we propose the following hypothesis H2.

H2. Labour flexibility positively influences process innovation deployment preparedness.

Mix flexibility

Mix flexibility is a key construct in defining flexible manufacturing capability (Zhang et al., 2003). Sethi and Sethi (1990) describe mix flexibility as the capability of the firms to produce mixtures of products in a more effective and economical way with their capacity. According to Zhang et al. (2003), customers value visible capabilities such as volume flexibility and mix flexibility rather than the internally oriented competencies such as machine flexibility, labour flexibility, material handling flexibility, and routing flexibility. This is because customers see how these capabilities can be used to increase their satisfaction. However, it has also been reported that mix flexibility cannot be achieved directly; they are attained through the implementation of flexible manufacturing competencies, which include machine, labour, material handling, and routing flexibilities (Zhang et al., 2003). Nevertheless, Zhang et al. (2003) indicated that a) mix flexibility has significant, positive, and direct impacts on customer satisfaction and that b) mix flexibility seems to have a greater impact on customer satisfaction than other types of flexibility.

Oke (2013) reveals that having mix flexibility and labour flexibility at the same time and their interaction should have a positive influence on product innovation in manufacturing plants. It seems logical to extend this assertion to manufacturing process innovation. However, mix flexibility needs management involvement, and it also demands more preparation in comparison to some other manufacturing flexibilities. The conceptualisation of manufacturing flexibility's influence on process innovation versus process innovation is an interesting one. According to Nemetz and Fry (1988), manufacturing flexibility can have more influence on process innovation in comparison with product innovation. Higher manufacturing flexibility would allow supporting evolving requirements, adapting to environment or system configuration changes, simplifying maintenance and repair, and improving the efficiency in resource utilisation (Ferreira et al., 2006). This efficiency is expected to impact positively on innovation deployment readiness. Whilst there are some insights into mix flexibility influences on product innovation, having some clarity about the link between mix flexibility and deployment readiness states, particularly process innovation deployment preparedness, will be helpful.

In this research, an attempt is made to understand the link between the mix flexibility and innovation deployment preparedness. Oke (2005) has noted that mix flexibility has a direct influence on the manufacturing firm's competitive performance. Zhang et al. (2003) have also mentioned mix flexibility is an external aspect of competition which clearly affects customer satisfaction. These studies help us to understand mix flexibility as a competitive advantage for companies' strategies. This is taken further in this thesis, in which it is posited that the degree of mix flexibility of an operation will influence a manufacturing company's preparedness to deploy process innovation. It can be an argument that mix flexibility helps a manufacturing company to produce a wide range of products, and due to the pressure and dedication mix flexibility may entail, increased mix flexibility may allow companies to be better prepared in getting ready to deploy process innovation. The following hypothesis, H3, is proposed.

H3. Mix flexibility influences process innovation deployment preparedness.

5.2.2.3 Deployment plan, Innovation deployment preparedness and full readiness

Designing and planning are highly significant functions of management, and it is necessary at each stage of process innovation deployment. Deployment starts with the decision to do something, i.e., to implement an idea of the initiative. The idea contains, wherever appropriate, information regarding the structure and system assistance, problem tracing, increased procedures, responsibilities, and duties pre-implementation, throughout implementation, and post-implementation. In all this, having a deployment plan in place will help.

The importance of deployment plans is a contested territory among planning scholars. Furthermore, plans are valued because they can encapsulate visions for the future, guide and regulate development, and serve as communicative signals about values and intentions that can influence a wide array of firm conditions (Kaiser and Godschalk 1995; Hopkins 2001; Berke and Godschalk 2009). A deployment model with a plan can encapsulate the deployment's basic scope, scale, structure, and focus. There is arguably no one right deployment model for all manufacturing process implementation situations.

A deployment plan, i.e., one that has a high chance of leading to successful deployments, specifies the deployment approach, execution and scope, and good plan for the deployment of the innovation initiative. Plans may include a) information on system support, b) responsibilities and duties prior to, throughout, and later implementation, c) schedule of deployment activities and d) problem tracking and escalation processes. Not all plans are formalised. Hence two approaches to deployment plans can be considered -

formal (explicit) and/or informal (implicit). Arguably, neither of these approaches is established to be superior in comparison to the other across all process innovation deployment situations, and neither will work one hundred per cent due, for example, to inherent uncertainties. Small firms may be more inclined towards informal approaches and may benefit most from that approach when compared with bigger firms due to differences in the characteristics of the firms (Barney 1991). A formal (explicit) approach usually starts by clarifying objectives and developing the necessary strategy that would lead to the completion of such objectives (Barney 1991). This results in lesser flexibility when the implementation of the plan starts. However, it lessens the confusion and allows for larger groups or individuals to follow a more uniform set of procedures. On the other hand, informal plans can be more suited to circumstances where changes occur rapidly, and, in such scenarios, informal plans can enable companies to better innovate whilst continually adapting (Barney 1991). Deployment plans (either explicit or implicit) can have a positive relationship with achieving a full readiness state regarding manufacturing process innovation. Therefore, the following hypotheses (H4 and H5) are proposed:

H4: Deployment plan positively influences attainment of full process innovation deployment readiness.

H5. Deployment plan positively influences process innovation deployment preparedness.

5.2.2.4 Climate for Innovation and Deployment Readiness

There is a multitude of options available to firm managers for boosting innovation which principally includes a climate of creativity, a haven for the invention of new ideas, the application of which can spur effective and efficient deployment of innovation initiatives and company growth. An organisation's climate can prove insightful regarding how the organisation behaves and governs itself, which may be mirrored in the methods, practices, and rewarding systems (Ahmed, 1998). In an assertion credited to Hellriegel and Slocum (1974), Asif (2011) stated that organisational climate assumes 'that individuals within a given subsystem or organisation and at a given hierarchical level should have similar perceptions about their climate'. It is worth noting, however, that the systems of each firm would interact with the organisational climate in different ways. Innovation is a direct influence on the organisational climate, especially through 'shared norms' between the organisation's employees as well as socialisation processes (Tesluk et al., 1997). There are reviews on work climate assessments and their effect on innovation (e.g. Hunter, Bedell &

Mumford, 2007). There appears to be a consensus in the literature that organisational innovation was largely influenced by work climate dimensions. According to Amabile et al. (1988), employees were encouraged to be independent as well as creative as part of the innovative organisational climate. For this reason, the organisational climate for innovation has been expressed as the 'degree to which organisation norms emphasise innovation' (West and Anderson 1996). Employees are more motivated to innovate if they identify with their work environment and see it as providing a suitable and supportive space for innovation (Klein and Sorra 1996). In Oke (2013), climate for innovation is defined as 'an environment that is the outcome of the practices and reward systems that are put in place to recognise and encourage creativity and innovation'. This definition of climate for innovation is adopted in this research. Climate represents the behaviour, attitudes and feelings of the organisation, which in turn affect its operational processes (or life) in terms of communications, problem-solving, decision making and how it learns. Not all firms are the same. Each has a different root system, and each reacts to the climate in differing ways. It can be hypothesised that to be fully ready to deploy process innovation, a manufacturing company requires an appropriate climate for innovation. Hence, the following hypothesis is put forward.

H6: Climate for innovation positively influences attainment of full process innovation deployment readiness.

In addition, as highlighted above, the degree of climate for Innovation can positively affect a manufacturing company's preparation to deploy process innovation. The following hypothesis (H7) is proposed:

H7: Climate for innovation positively influences process innovation deployment preparedness.

5.3 Hypothesis testing

In this research, structural equation modelling (SEM) with the maximum likelihood estimation method has been used to test the hypotheses. AMOS 26.0 software is used to test the proposed model, and the results are presented in Section 5.4. The conceptual framework developed in Section 5.2 is evaluated using data collected from a structured questionnaire survey. This section, Section 5.3, describes the sampling method and approach for collecting data.

5.3.1 Survey instrument

Our study primarily adopts well-established and applied scales from prior research, which enhance the validity and reliability of the findings. Table 28 contains the definitions of the constructs used and the measures of the constructs.

Mix and Labour Flexibility are measured by six and five items, respectively, adopted from Oke (2013). Mix flexibility items reflect the firm's ability to produce different mixtures of products more effective and efficient with the firm's actual capacity. Labour flexibility items reflect the employee's ability to work and deliver different types of manufacturing jobs more effectively and efficiently. Climate for Innovation is assessed by three items, one of the measurement items represents and assesses the availability of resources, guidance, means and encouragement that top management provides in support of the deployment. The other two items of the climate for innovation construct reflect the reward system and the organisation's environment for innovation (Oke, 2013).

The measures for deployment plan, innovation deployment preparedness, and full readiness to deploy process innovation are created by the researcher. Deployment plan represents a good, detailed plan for implementing an innovation initiative in a target environment and is measured by five items. Innovation deployment preparedness is measured by four items that reflect deployment framework and organisational team preparedness to implement innovation (Adams et al., 2000; Ahmadi et al., 2015). Fully readiness to deploy innovation is measured by one item asking the management team whether they are fully ready prior to deploy their process innovation initiatives.

A multiple-item, seven-point Likert-type scale (1= "strongly disagree"… 7= "strongly agree") is used throughout to operationalise the constructs. In addition to measuring the constructs, the questionnaire included information about the respondents' demographics (e.g., industry, size, position, experience).

A pilot panel of five manufacturing managers, five postgraduate students, and three operations management university lecturers are used to validate the constructs' structure and relevancy. The panel carries out a pre-test of the questionnaire. The panel suggested minor changes to ensure that the constructs are well-structured, appropriately capturing the key factors.

Table 28: Definition of research constructs

Construct	Definition
Deployment plan	A deployment plan is a detailed proposal for implementing an innovation initiative in a target environment (Created by the researcher). A deployment plan can be either: a) explicitly set out and formalised, or b) informally set out, i.e. implicit
Mix Flexibility	The ability of the organisation to produce different combinations of products economically and effectively given certain capacity (Zhang et al., 2003), Boyer and Leong (1996), Sethi and Sethi (1990), Gupta and Somers (1992), (Oke, 2013)
Labour Flexibility	The ability of the workforce to perform a broad range of manufacturing tasks economically and effectively (Oke, 2013), Upton (1994), Hyun and Ahn (1992), Ramasesh and Jayakumar (1991)
Climate for Innovation	An environment that is the outcome of the practices and reward systems that are put in place to recognise and encourage creativity and innovation. Oke (2013), Scott and Bruce (1994)
Innovation Deployment Preparedness (Is the state of readiness)	Innovation Deployment Preparedness is the state of readiness. Having a comprehensive deployment team in place with the deployment framework selected to guide the implementation innovation process. And having a communications plan to share the progress of the implementation plan with multiple stakeholders, regardless of their direct involvement, is in place and access to real-time information.
Innovation Deployment Full Readiness	Fully ready prior to deploying the process innovation initiatives.

Questionnaire items

Deployment plan (DP)

The measures for a deployment plan were created by the researcher and have not been applied in previous studies.

DP1- Deployment plan has timelines for actions. The plan provides a schedule of activities to be accomplished.

DP2- Deployment plan provides a description of the tasks/activities involved in a manufacturing process deployment.

DP3- Deployment plan describes the support resources required for the deployment, as well as the documentation, necessary personnel and training requirements, outstanding issues, and deployment impacts on the manufacturing environment.

DP4- Deployment plan describes committed and proposed staffing requirements. Describe the training, if any, to be provided for staff.

DP5- We consider our organisation to be innovative.

Mix Flexibility (MF) **(Zhang et al., 2003)**

MF1- We can produce a wide variety of products in our plants.

Table continues-next page.

MF2- We can produce different product types without major changeover. **MF3-** We can build different products in the same plants at the same time. **MF4-** We can produce, simultaneously or periodically, multiple products in a steady-state operating mode. **MF5-** We can vary product combinations from one period to the next. **MF6-** We can change over quickly from one product to another.	
Labour Flexibility (LF)	**Oke (2013), Scott and Bruce (1994)**
LF1- Workers can perform many types of operations effectively. **LF2-** A typical worker can use many different tools effectively. **LF3-** Cross-trained workers can perform a broad range of manufacturing tasks effectively in the organisation. **LF4-** Workers can operate various types of machines. **LF5-** Workers can be transferred easily between organisational units.	
Climate for Innovation (CfI)	**Oke (2013), Scott and Bruce (1994)**
CfI1- The reward system here encourages innovation. **CfI2-** The organisation publicly recognises those who are innovative. **CfI3-** Top management provides resources, guidance, means and encouragement.	
Innovation Deployment Preparedness (IDP) *The measures for Innovation Deployment Preparedness were created by the researcher and have not been applied in previous studies.*	
IDP1- There is a comprehensive deployment team in place (e.g., representatives from multiple areas of the organisation). **IDP2-** There is a deployment framework selected to guide the implementation innovation process. **IDP3-** There is a communications plan to share the progress of the implementation plan with multiple stakeholders, regardless of their direct involvement. **IDP4-** We have access to real-time information.	
Innovation Deployment Full Readiness (IDFR) *The measures for Innovation Deployment Full Readiness were created by the researcher and have not been applied in previous studies.*	
IDFR1-We are fully ready prior to deploying the process innovation initiatives.	

5.3.2 Sampling and data collection

The questionnaire was designed to gather data from professional manufacturing managers working in the UK with at least one year of experience implementing process innovation in a manufacturing organisation (s).

Using various sources of a dataset of UK information systems, with a primary focus on the FAME database, a random sample was gathered to represent a wide variety of managers in the manufacturing sector of the UK. The list was screened and revised based on the accessibility of the availability of active online and offline contact data to facilitate follow-ups and a good response rate. Seven hundred manufacturing companies were selected randomly from the databases to construct the sample. Consequently, 700 questionnaires were sent to manufacturing managers in various manufacturing sectors and industries. From the 700-survey distributed, 101 manufacturing managers' useful responses were obtained, limited to one participant each from each company. With the system used for collecting data (Online Bristol Survey), it was possible to automatically not accept incomplete responses. The 101 usable responses from a population of 700 companies ready for further analysis represent an overall response rate of 14.4%.

Non-response bias is tested by comparing the early and late respondents (Armstrong and Overton, 1977). The analysis reveals that there are no significant differences between the first and late replies in the entire sample. Moreover, we applied the single common factor analysis available in the Statistical Package for Social Sciences (SPSS). The result indicated that 38.806 per cent of variance was explained by a single component factor of all items. This suggested that the data did not exhibit significant common method bias (Podsakoff et al., 2003). The approach to identifying the sampling frame and testing for the non-response bias was described in the research methodology chapter, Chapter 3, in Section 3.4.5.

5.4 Results

5.4.1 Demographics of respondents

The demographics of respondents are listed in table 29 below, as follows:

Table 29:Demographics of respondents

Firm characteristics	Value	Frequency	Percentage (%)
Experience	[< 1 year]	0	0
	[1 – 3 years]	32	31.7
	[4 – 5 years]	29	28.7
	[> 5 years]	40	39.6
Business/Organisation type	Financial service	0	0
	Automotive industry	6	5.9
	Construction	0	0
	IT-Technology	2	2
	Electrical industry	1	1
	Manufacturing	87	86.1
	Service industry	1	1
	Telecommunication	0	0
	Mechanical industry	3	3
	Other	1	1
Size of organisation	[< 20]	0	0
	[20 – 50]	10	9.9
	[51 – 100]	12	11.9
	[101 – 200]	38	37.6
	[201 – 500]	21	20.8
	[501 – 1000]	14	13.9
	[> 1000]	6	5.9

The respondent's companies are distributed from small to very large enterprises. The distribution is illustrated in Figure 19, showing that the dominant profile of respondents belongs to the small and medium-sized enterprises (SMEs), which accounted for about 60% of the total distribution.

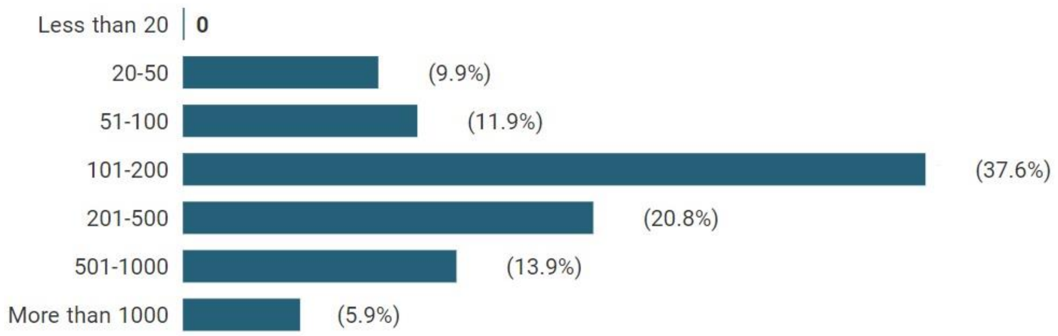


Figure 19: Distribution of the Respondent's Company Size (No of Employees)

A descriptive statistic of the participant's years of experience is shown in Figure 20. It is observed that over 39.6% of the respondents have been engaged in the industry for a period of 5 years and above. 28.7% of the respondents have been engaged in the industry for 4 to 5 years, while 31.7% of respondents confirmed to have been engaged in the industry for a period of 1 to 3years. This result shows that a large percentage of the respondents have the necessary experience needed for the study.

Figure 20: Years of Experience.

Figure 21 below shows the size of the companies in the sample that deploy process innovation. It also shows the split between formal and informal deployment plans when implementing process innovation. It is seen that a higher percentage of the companies that deploy process innovations are small and medium-sized companies (SMEs). It is observed that most SMEs (30%) deployed the Informal deployment plan, followed by medium-sized companies (25%) and large size companies (18%). Also, it was observed that for the informal deployment plan, the SMEs had the highest percentage of deployment (33%), followed by the small firms (28%) and the medium and large firms (17%), respectively.

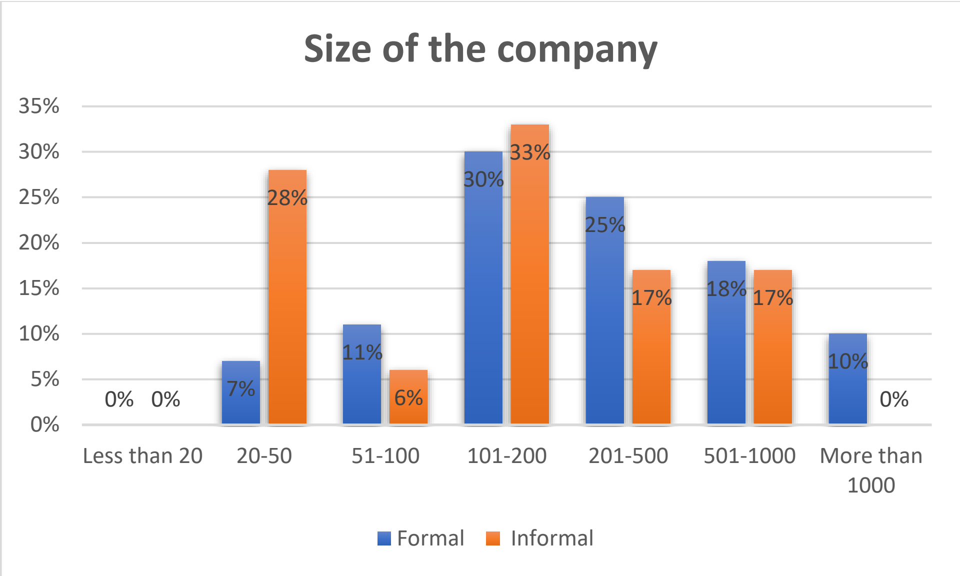


Figure 21: the size of the companies that deploy process innovation

The results also show that there is overall support for both formal and informal planning across various organisations, as illustrated in Figure 22 below.

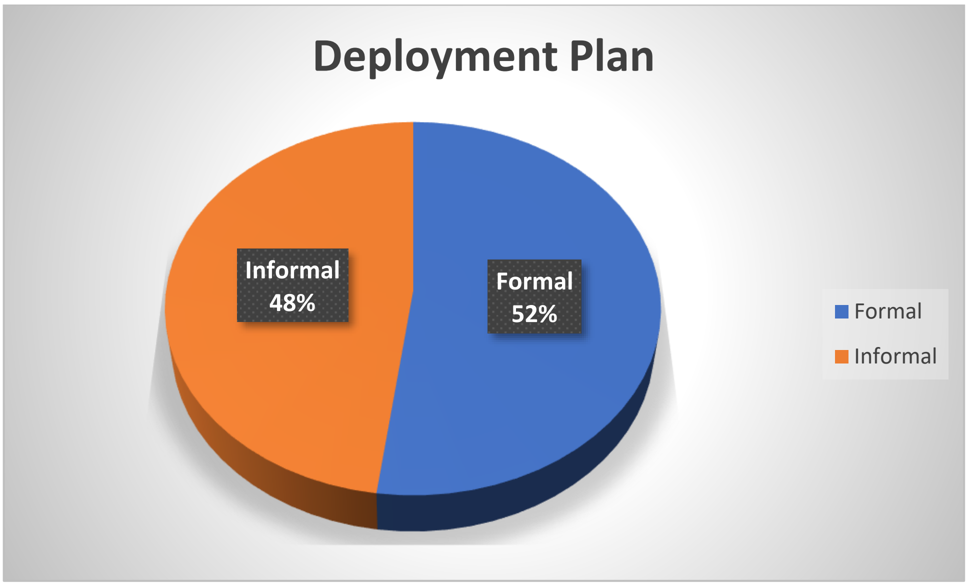


Figure 22: formal VS informal planning

Figure 23 below shows the level of experience companies in the survey has in deploying process innovation. The figure depicts that companies with a higher level of experience (51%) tend to implement process innovation than companies with lesser years of experience 4-5 years (25%) and 1-3years (24%). Regarding using a formal deployment plan, companies with a higher level of experience of five years and above had a greater percentage (51%) of deployment than companies with lower experience. Likewise, regarding the use of informal deployment plans, it is also found that more experienced companies (50%) take the lead in the deployment process and the less experienced companies for 4-5 years (28%) and 1-3years (22%) following behind.

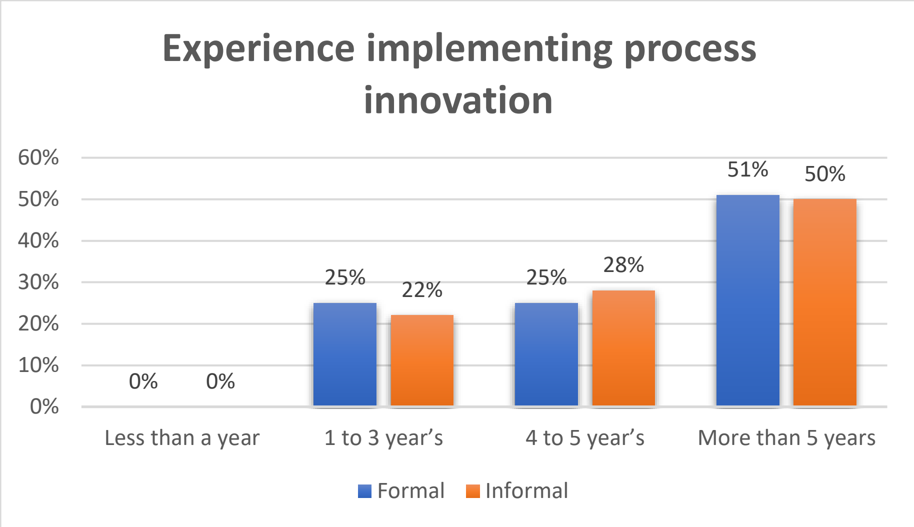


Figure 23: experience level of the companies that deploy process innovation

5.4.2 Reliability, Validity (Goodness of fit) and the Structural Model

The items in the conceptual framework were tested for one-dimensionality using exploratory factor analysis (EFA). Promax was used to do the EFA with principal component analysis (PCA) and the Kaiser normalisation rotation method (Dien et al., 2005). The factor loadings converged in seven iterations. Table 30 shows the findings of the EFA.

The Kaiser-Meyer-Olkin (KMO) value derived from the EFA is higher than Kaiser's recommended minimum value of 0.70 Kaiser (1974). The total variation explained is 71.6 per cent, which exceeds Hair et al. (2010) recommended threshold value of 60%. Hair et al. (2016) suggest that factor loadings above 0.40 are sufficient for explorative research. On the constructs they assess, all measuring items have above (above 0.50) loadings, which is adequate for this study. Confirmatory factor analysis (CFA) in SPSS 28.0 was used to conduct reliability and validity tests. The constructs' unidimensionality was also tested using CFA. Amos 28.0 software was used to test the overall measurement model's fit (Blunch, 2017). The foundations of Amos 28.0 are regression, path, and principal components factor analysis. It easily produces standardised regression coefficients for routes in structural models and factor loadings for measurement items. Each item was linked to its relevant latent variable in this study's conceptual framework, which has five variables. The model fit indices were found to be adequate, with CMIN/DF = 1.02, CFI = 1.00, TLI=0.999, RMSEA = 0.014, and PClose = 0.447 (Hu and Bentler, 1999).

To assess dependability, Cronbach's alpha (CA) and composite reliability (CR) was used. This study's trustworthiness is acceptable because Cronbach's value is greater than 0.60 (Taber, 2018), and the CR value is greater than 0.70 (Hair et al., 2010). Convergent and discriminant validity are used to assess validity; convergence validity is achieved when the standardised factor loading is larger than 0.50 and the average variance extracted (AVE) value is greater than 0.50, as it is in this study.

In summary, Tables 30 and 31 below show the reliability and validity results. Table 30 shows that all Cronbach's values are greater than 0.60, and all CR values are greater than 0.70, indicating that the data is reliable. AVE values are greater than 0.50, and all correlation coefficients are less than the square roots of the AVE value (Table 30), indicating convergent and discriminant validity. Finally, the scale is said to exhibits discriminant validity if the AVE value is bigger than the correlation coefficients square (Ab Hamid et al., 2017), which is the case in this investigation

Table 30: Measurement items

Constructs	**Items**	**Loadings**	**AVE**	**CR**	**Cronbach's α**
Deployment plan (DP)	DP1	0.904	0.689594	0.917187	.905
	DP2	0.855			
	DP3	0.806			
	DP4	0.803			
	DP5	0.778			
Mix Flexibility (MF)	MF1	0.933	0.551057	0.929237	0.898
	MF2	0.819			
	MF3	0.808			
	MF4	0.778			
	MF5	0.712			
	MF6	0.666			
Labour Flexibility (LF)	LF1	0.958	0.614481	0.885553	.0936
	LF2	0.899			
	LF3	0.722			
	LF4	0.674			
	LF5	0.609			
Innovation Deployment Preparedness (IDP)	IDP1	0.909	0.600319	0.853672	0.901
	IDP2	0.838			
	IDP3	0.750			

Table continues-next page.

	IDP4	0.557			
Climate for Innovation (CfI)	CfI1	0.870	0.644607	0.842817	0.887
	CfI2	0.861			
	CfI3	0.660			
Innovation Fully Ready (IFR)	IFR				
KMO	**0.822**				

Table 31: Discriminant validity

	AVE	DP	MF	LF	IDP	CfI
Deployment plan (DP)	**0.689594**	**0.83**				
Mix Flexibility (MF)	**0.551057**	.218	**0.742**			
Labour Flexibility (LF)	**0.614481**	.553	.372	**0.784**		
Innovation Deployment Preparedness (IDP)	**0.600319**	.353	.104	.436	**0.803**	
Climate for Innovation (CfI)	**0.644607**	.354	.283	.500	.442	**0.775**

Multicollinearity was examined before the proposed correlations were tested. The maximum variance inflation factors (VIF) value derived from the data is 2.353, indicating that multicollinearity is not an issue because the VIF number is less than 3, as recommended by Ringle and Sarstedt (2016). The structural model is further evaluated by looking at the variation explained by exogenous variables (R2), as well as the predictive usefulness of the model using path coefficients (β) and significant levels (p-values).

Table 32 shows the outcomes of the hypothesis testing.

Table 32: Results of the hypothesis tests

Hypotheses	Coefficient (β)	T statistics	P values	Inner VIFs	Supported
H1: IDP → IFR	0.33	5.034	***	1.380	Yes
H2: MF → IDP	-0.08	-0.816	.405	1.158	No
H3: LF → IDP	0.38	3.089	.002	1.771	Yes
H4: DP → IFR	0.32	4.717	***	1.386	Yes
H5: DP → IDP	0.08	0.745	.447	1.617	No
H6: CfI → IFR	0.48	8.105	***	1.543	Yes
H7: CfI → IDP	0.25	2.854	.004	1.531	Yes

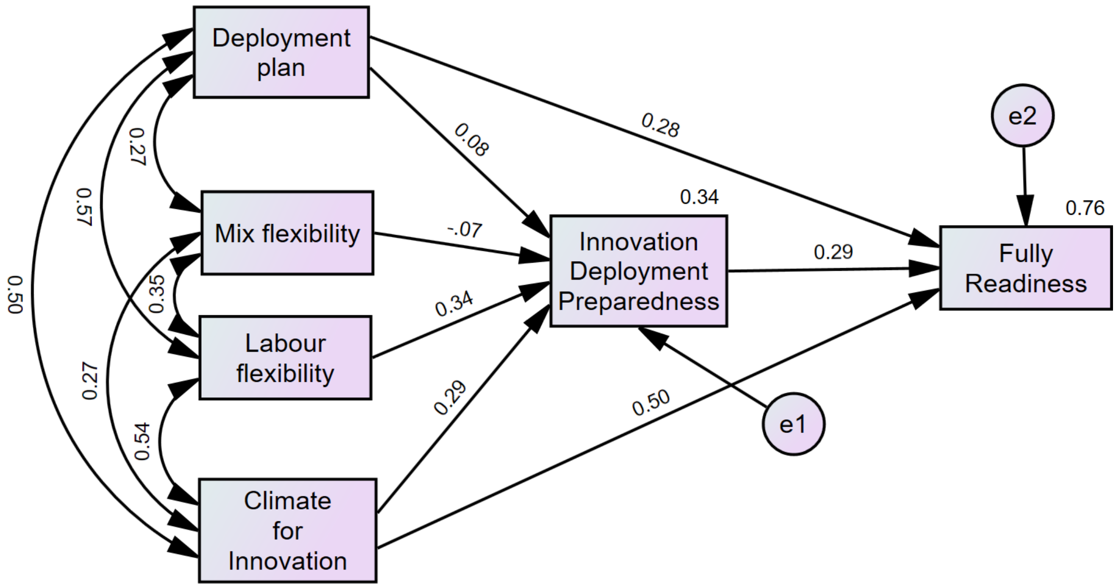


Figure 24: standardised path coefficients

5.5 Additional Results and Discussion

The results of the study, as indicated in Table 32 and Figure 24, indicate that a deployment plan will have a positive and significant influence on achieving a state of full readiness to deploy manufacturing process innovation, thus supporting Hypothesis 4 (β = 0.32, p = 0.000). However, Hypothesis 5 states that a deployment plan will have a positive and significant influence on Innovation, and this was supported (β = 0.08, p =0.447). in the evaluation. It appears that a deployment plan may not be mandatory when preparing for deployment but achieving a state of full readiness to deploy requires a deployment plan.

According to the results, the climate for Innovation has a positive and significant influence on the full readiness, thereby indicating support for Hypothesis 7 (β = 0.48, p = 0.000), and it also has a positive and significant influence on innovation deployment preparedness, thereby indicating support for Hypothesis 6 (β = 0.25, p = 0.004). This is expected and reinforces the results of previous studies on the influence of climate for innovation on innovation implementation (Somech & Drach-Zahavy, 2013). The results support the idea that innovation is a direct influence on the climate, especially through 'shared norms' between the organisation's employees as well as socialisation processes (Tesluk et al., 1997).

Hypothesis 1, which postulates a positive and significant influence of innovation deployment preparedness on full readiness, is supported ($\beta = 0.33$, $P = 0.000$). This is a significant result as it establishes a positive link between preparedness and full readiness in the context of manufacturing process innovation. Moreover, it reinforces the points elucidated by Hill and Chambers (1991) and Ramasesh and Jayakumar (1991) regarding the importance of flexibility in preparing to be ready for something.

The result regarding manufacturing flexibility is diverse. Labour flexibility is found to have a positive and significant influence on preparedness, thus supporting Hypothesis 3 ($\beta = 0.38$, $p = 0.002$). However, the results indicate that Hypothesis 2 ($\beta = -0.08$, $p = 0.405$) is not supported. There is not enough support for a hypothesis that mix flexibility influences process innovation deployment preparedness.

It is worth noting that although no distinction is made in the hypothesis concerning deployment regarding whether they are formal or informal, it appears that overall, the idea that plans are valued comes out in the results and reinforces the view that plans can encapsulate visions for the future, provide a schedule of activities to be accomplished, guide and regulate development, and serve as communicative signals about values and intentions that can influence a wide array of firm conditions (Kaiser and Godschalk 1995; Hopkins 2001; Berke and Godschalk 2009). This is more so when aiming for a full readiness state. Manufacturing companies need to have a deployment plan in place to be fully ready for process innovation deployment, but such plans may not be necessary when preparing for innovation; perhaps a working deployment plan may be sufficient when preparing for process innovation deployments. In essence, these results allude to deployment plan quality and the choices that need to be made in the acceptable levels of deployment plan quality at various states of process innovation deployment readiness.

The survey also collects data on the perceptions of manufacturing managers regarding the following.

1) The level of confidence regarding implementation success their company would normally require for them to proceed with implementing process innovation.
2) The ways they feel planning can help improve the successful implementation of process innovation.
3) What they think a deployment plan should contain in the context of implementing manufacturing process innovation?

The first question was meant to ascertain to what degree of readiness would they require before deploying their process innovation initiatives. The result shows that most of the manufacturing managers agree that they need to be ready before deploying process innovation. However, they would not normally require to be fully ready before deploying process innovation. Over 60% of the managers stated that they would normally need more than 70% level of readiness to deploy their innovation initiatives, with only 1% of the companies in the sample saying that they needed to be over 95% ready. Whilst the 95% appears to be an exceptionally high standard to attain, most appear satisfied with a readiness band of 70%-80%. None of the respondents reported wanting to deploy at a readiness band of 40% and below. The implication of this result is that although most managers do recognise the importance of readiness, some factors may affect their acceptable level of readiness to proceed with deployment. For instance, a deployment readiness plan may be revised to include a substantial risk plan, particularly in states where deployment readiness is relatively low (Javahernia & Sunmola, 2017). There is also an option of pilot deployment and using the pilot to enhance their readiness, sometimes beyond the original threshold readiness band.

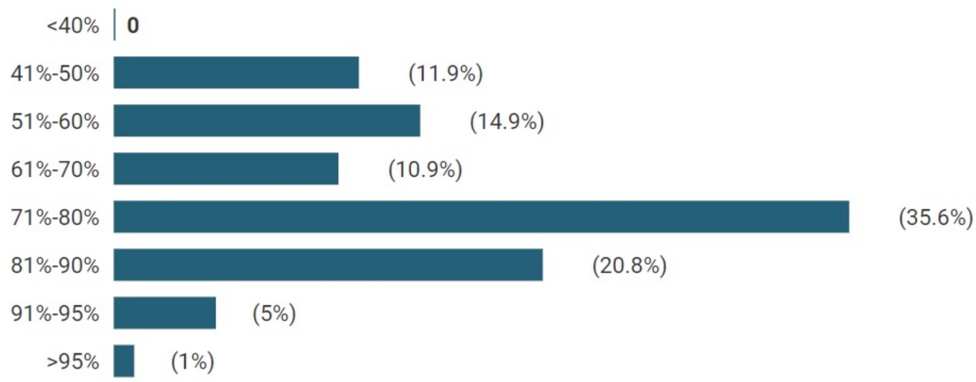


Figure 25: Distribution of Process Innovation Deployment Readiness Bands

The second question is directed at understanding how planning can help improve the successful implementation of process innovation. All participants felt that planning could help, and the following are typical comments that were made.

- Ensuring all people are aligned with the goals of the organisation.
- The planning phase is the moment where you can take the time to analyse the improvement opportunity to be more assertive and boost your success rate in the implementation phase.
- In front of every new project, even of simple improvement of a particular sector of the manufacturing, correctly planning each action leads to a saving of time and

resources because the budget has been rationally divided and the tasks have been hierarchised according to their priority. Furthermore, since the planning phase is discussed among more professionals, everyone is aware of the steps to follow and how to proceed. To conclude, a well-organised plan provides for the potential risks and problems that may occur and, in doing so, reduces them.

- By identifying the opportunities early and engaging with all stakeholders to effect the desired change.
- Planning in financial resources in order to improve purchase planning.
- Selecting go international strategy in our companies.
- Working on culture first

In question three, participants alluded to what they believe a deployment plan should be contained in the context of implementing manufacturing process innovation.

- A goal for each member is to innovate from the norm if possible
- Topic analysis
- Team
- target
- Implementation plan with deadline and status
- Check the achievements/ lessons learned
- Cost
- Quality
- Timeline
- Risk
- Business Culture
- Product lifecycle
- Communication
- what, why, when, who, where, how
- Human resource issues are very important
- Role of each individual and a clear plan

5.6 Chapter summary

This chapter reports on a conceptual framework developed for process innovation deployment readiness in manufacturing. The constructs investigated were, and most of the constructs were all shown to positively influence either preparedness to deploy, achieving a full readiness state to deploy or both. The conceptual framework is evaluated using data collected from a questionnaire survey of manufacturing managers. Perceptions of the manufacturing managers solicited for three additional questions in the questionnaire corroborate aspects of the conceptual framework, particularly regarding the need for preparation in deploying process innovation in manufacturing and the role of deployment plan in the methodology for manufacturing process innovation. It, however, also appears to suggest that achieving a full readiness state to deploy may not be a typical practice, i.e., manufacturing companies may deploy their process innovation once they have reached a satisfactory level of preparedness, somewhere around 70%-80% of being fully ready to deploy.

6 Fuzzy Assessment of Deployment Readiness Level

6.1 Introduction

Assessment of manufacturing process innovation deployment readiness level is an important and essential step in the methodology of implementing process innovation. Knowing the deployment level is important for several reasons, including ascertaining whether (a go)/(no go) decision regarding the implementation of a process innovation initiative. Also important is the use of the assessed deployment readiness level and associated feedback on improvement areas as a springboard for improving readiness to deploy. Inability to appropriately assess deployment readiness levels can impact implementation success, which may also create an atmosphere of ambiguity amongst potential UK small-to-medium size manufacturing (SMEs) lean users (Achanga et al. 2006a), heightening challenges of implementing necessary innovations in manufacturing, particularly within SMEs.

This chapter presents a method of assessing the manufacturing process innovation deployment readiness level. It differs from existing methods in several ways, chiefly in that it uses a data structure consisting of attributes, factors and dimensions of manufacturing process innovation compiled using manufacturing industry experts. In addition, the assessment is based on linguistic variables within a fuzzy logic setting, which allows assessors to accommodate several types of input values, including those that are based on natural language, vague, distorted, or imprecise data. Fuzzy logic uses knowledge about a specific domain to arrive at a solution to a problem, as demonstrated by authors such as (Rao and Pratihar, 2006; Parent et al.2007; Lau et al., 2005; Muthus et al.2001). The domain in this thesis is manufacturing process innovation deployment readiness. The approach adopted in the assessment is described in Section 6.2. This is developed further in Section 6.3 by detailing the fuzzy expressions involved in the approach. A case study conducted in a contract manufacturing company based in the UK is used to illustrate the approach in Section 6.4. The results obtained from the case study are discussed in Section 6.5, and the chapter ends in Section 6.6 with a chapter summary.

6.2 Fuzzy assessment approach

The fuzzy assessment approach developed consists of seven main steps, shown in Figure 26 below.

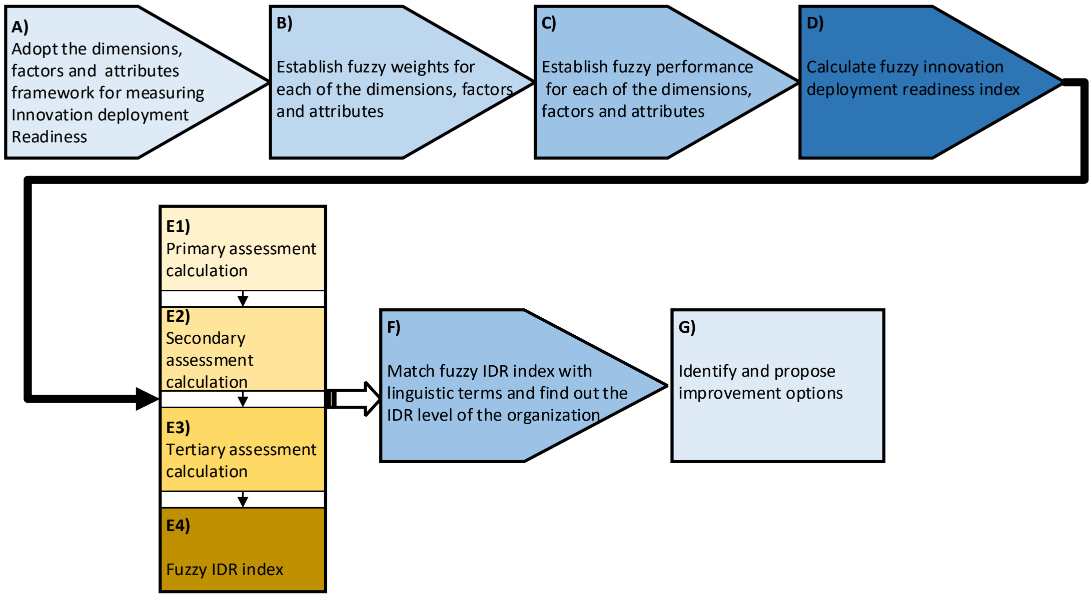


Figure 26:The fuzzy logic approach adopted in this research.

The first phase is to select an appropriate set of dimensions, factors, and attributes as the data structure to organise and drive the assessment. As shall be seen above (Figure 27 - box A), the assessment relies on the adaptation of the data structure to the specific assessment being conducted. In this thesis, as an illustration, the set of dimensions, factors and attributes developed in Chapter 4 and listed in Table 27 is used. Following the adoption of the set of dimensions, factors and attributes to use, fuzzy weights are attached to each of the dimensions, factors and attributes (Figure 28 - box B). In essence, the deployment readiness level is an aggregation of weighted values associated with the dimensions, factors, and attributes of the manufacturing process innovation deployment under consideration. In addition, performance values are attached to the attributes, and it is the performance levels and established weights that determine the overall process innovation deployment readiness level (Figure 29 - box C&D). The level is derived from a set of fuzzy logic calculations organised into four main steps – primary, secondary, tertiary, and a fuzzy innovation deployment readiness index (Figure 26 - box E1,2,3,4). The calculated Fuzzy IDR index is then mapped to an IDR level (Figure 30 - box F). Finally, areas of improvement are identified based on a deployment performance threshold recommended by the manufacturing company (Figure 31 - box G). The details of the fuzzy logic expressions involved in the assessment are presented in the next section, i.e., Section 6.3 below.

6.3 Assessment of Innovation Deployment Readiness Level

In line with the approach described in Section 6.2 above, the innovation deployment readiness assessment model presented in this thesis is based on an Innovation deployment readiness assessment template shown in Table 33 below.

Table 33:The Innovation Deployment Readiness Assessment Template

Dimensions of Innovation deployment Readiness		Factors of Innovation deployment Readiness		Attributes of Innovation deployment Readiness		
Dimensions i	Weight W_i	Factor j	Weight W_{ij}	Attribute k	Weight W_{ijk}	Performance R_{ijk}
1	W_1	1	W_{11}	1	W_{111}	R_{111}
●	●	●	●	●	●	●
●	●	●	●	●	●	●
●	●	●	●	●	●	●
I	W_I	J	W_{IJ}	K	W_{IJK}	R_{IJK}

The template is based on the use of a set of IDR dimensions, factors, and attributes. Readiness dimensions, factors, and attributes are represented by $i \in \{1\ldots,I\}$, $j \in \{1\ldots,J\}$, and $k \in \{1,\ldots,K\}$ respectively, where I, J, K are the numbers of the dimensions, factors and attributes involved in the IDR assessment. The assessor specifies each of the I dimensions, J factors and K attributes. The performance values of each of the readiness attributes are then recorded to indicate importance ratings R_{ijk}. Additionally, weights are attached to each of the dimensions, factors, and attributes (i.e., weights W). Importance and performance ratings are specified as linguistic values. Tables 34 and 35 show the linguistic variables and their values used to express performance ratings and importance ratings in this thesis. These variables and values are not necessarily cast in stone, alternative appropriate set of performance and importance ratings can be used.

Table 34: Linguistic Variables and Associated Fuzzy Numbers for Performance Rating

Performance rating				
Linguistic variable		Fuzzy number		
Scale	Variable	N 1	N 2	N 3
Worst	W	0	0.5	1.5
Very poor	VP	1	2	3
Poor	P	2	3.5	5
Fair	F	3	5	7
Good	G	5	6.5	8
Very good	VG	7	8	9
Excellent	E	8.5	9.5	10

Table 35: Linguistic Variables and Associated Fuzzy Numbers for Importance Rating.

Importance rating				
Linguistic variable		Fuzzy number		
Scale	Variable	N 1	N 2	N 3
Very low	VL	0.00	0.05	0.15
Low	L	0.10	0.20	0.30
Fairly low	FL	0.20	0.35	0.50
Medium	M	0.30	0.50	0.70
Fairly high	FH	0.50	0.65	0.80
High	H	0.70	0.80	0.90
Very high	VH	0.85	0.95	1.00

As explained in Section 6.2. above, the calculations are carried out in four steps.

Primary evaluation measurement

In primary evaluation measurement, the innovation deployment readiness contribution of j^{th} factor in k^{th} The performance attribute is calculated using Equation (6.1).

$$\mathrm{IDR}_{jk} = \frac{\sum_i W_{ijk} \otimes R_{ijk}}{\sum_i W_{ijk}} \tag{6.1}$$

IDR_{jk} = Innovation deployment readiness (IDR) contribution of factor j^{th} for the k^{th} performance attribute.

R_{ijk} = Performance rating of k^{th} attribute for the j^{th} factor and the i^{th} performance attribute.

W_{ijk} = Importance weight of k^{th} attribute for the j^{th} factor and the i^{th} performance attribute.

Secondary evaluation measurement

In the secondary evaluation measurement, the process innovation deployment readiness contribution of the j^{th} factor is calculated using Equation (6.2).

$$\mathrm{IDR}_j = \frac{\sum_j W_{jk} \otimes IDR_{jk}}{\sum_j W_{jk}} \tag{6.2}$$

IDR_j = Innovation deployment readiness contribution of factor j^{th}.
W_{jk} = Importance weight of j^{th} factor in i^{th} dimension.
IDR_{jk} = Innovation deployment readiness contribution of factor j^{th} for the k^{th} performance attribute, calculated in Equation 6.1. above.

Tertiary evaluation measurement

In tertiary evaluation measurement, the Fuzzy Deployment Readiness (FIDR) index is computed using Equation 6.3 below. The Fuzzy IDR index represents the overall fuzzy assessment of the process innovation deployment level. This is calculated using equation (6.3).

$$\mathrm{FIDR} = \frac{\sum_k W_k \otimes IDR_j}{\sum_k W_k} \tag{6.3}$$

FIDR = overall fuzzy process innovation deployment level
$\mathrm{W_k}$ = Importance weight of k^{th} dimension.
IDR_j = Innovation deployment readiness contribution of factor j^{th}, calculated in Equation 6.2. above

Manufacturing managers and other stakeholders would find it useful to work with an easier to understand grading scale for process innovation deployment readiness (PIDR) level. In this thesis, a 7-point Likert scale is adopted, namely from ‘Not at all Ready’ to ‘Fully Ready’, as illustrated in Figure 27 below. Fuzzy numbers were allocated to the scale, as shown in Table 36 below.

Figure 32: Innovation Deployment Readiness Level

Table 36: Linguistic Variables and Associated Fuzzy Numbers for Process Innovation Deployment Readiness Levels

Process Innovation Deployment Readiness Level index (IDRLi)				
Levels		Fuzzy number		
Scale	Variable	N 1	N 2	N 3
Fully Ready	FR	8.5	9.5	10
Very strongly Ready	VSR	7	8	9
Very Ready	VR	5	6.5	8
Ready	R	3	5	7
Moderately Ready	MR	2	3.5	5
Slightly Ready	SR	1	2	3
Not Ready at All	NRaA	0	0.5	1.5

To establish the PIDR level in Figure 27 and Table 36 above that appropriately maps to the calculated Fuzzy IDR obtained from Equation 6.3, a Euclidean distance method specified in Equation (6.4) below is used. Equation (6.4) is used to compute the distances between each PIDR level value in Table 36 and the Fuzzy IDR calculated in Equation 6.3. The resulting PIDR level is established as the minimum of the computed Euclidean distances, i.e., the closest match.

$$D(FIDR, PIDR_i) = \left\{\sum (f_{FIDR}(x) - f_{PIDRi}(x))^2\right\}^{1/2} \qquad (6.4)$$

The following section, i.e. Section 6.4, describes a case study to illustrate the fuzzy approach.

6.4 Case study

The fuzzy-logic based approach to assessing the manufacturing process innovation deployment readiness level of a manufacturing company, developed in this thesis, is validated in a contract manufacturing company based in the UK. The company is referred to in this thesis as Company Z. Contract manufacturing serves companies and stakeholders in their sector by providing product development and manufacturing services to their clients on a contractual basis. Company Z operates in the electronics sector. This case study arises from Company Z wanting to assess their readiness to deploy an innovative process of reconfigurable manufacturing in their company.

6.4.1 Assessment of Innovation Deployment Readiness in Company Z

The readiness assessment for Company Z is conducted in three stages. In the initial step, the aim was to agree on the assessment process with the company's management. Therefore, the process was first introduced to Company Z, who subsequently agreed to use the fuzzy assessment process developed in this thesis. The assessment for Company Z is based on the assessment template illustrated in Table 33 and the recommended data structure regarding a specific set of the specific set of deployment readiness dimensions, factors, and attributes presented in Chapter 4, Table 27.

In other to simplify data collection and make the fuzzy logic calculations described in Section 6.3 easier, a computational tool is developed. Table 37 shows the data collected from Company Z along with the dimensions, factors, and attributes used. The linguistic variables in Tables 34 and 35 (Section 6.3) regarding the importance weights and the performance ratings are used in the case study.

Table 37:Innovation Deployment Readiness for performance ratings and importance weights

Dimensions		**Factors**		**Attributes**		
Dimensions	**Wi**	**Criteria**	**W_{ij}**	**Attributes**	**W**	**R_{ijk}**
Context	**H**	**Vision and Strategic Plan**	**H**	Alignment of innovation strategy to mission, goals and business strategy	**H**	**VG**
				Process innovation implementation vision	**H**	**G**
				Strategy and Strategic Alignment, Link to customer and business strategy.	**H**	**VG**
				Clarity of Expectation and Constraints	**H**	**VG**
				Standardize procedures for deployment.	**H**	**VG**
				Ability to communicate vision and mission	**H**	**VG**
		Innovation Context	**VH**	The maturity level of the innovation	**VH**	**G**
				Knowledge and understanding of the new processes and their workflow.	**VH**	**VG**
				Protection of innovation	**VH**	**G**
				Specific and enabling infrastructure	**VH**	**VG**

Table continues-next page.

		Organisational and Leadership Context	**H**	Organisational members' shared resolve to implement the process innovation (Deployment commitment),	**H**	**G**
				Organisational members' shared belief in their collective capability to do so (Deployment efficacy),	**H**	**G**
				Drive to guide and support the process innovation deployment (Support for the deployment),	**H**	**G**
				Ability to handle staff with poor performance.	**H**	**G**
				Organisational process maturity	**H**	**G**
				Resilient and able to deal with frustration.	**H**	**G**
				Organization Structure, Capability, Barrier	**H**	**VG**
				Acquired leadership abilities, Understand and support, Management and Leadership	**H**	**G**
				Willing to assess and accept changes.	**H**	**VG**
				Reward system and associated processes that facilitate process innovation deployment (Deployment processes) and	**H**	**G**
				There are organisation compatibility/working practices between members.	**H**	**G**
		External Factors	**M**	environmental and social uncertainty	**M**	**G**
				suppliers and contractors and their cooperation	**M**	**VG**
				Availability of external support services	**M**	**VG**
				national and international business environment of supporting industries	**M**	**VG**
				Government support, policies and regulations, and Legal environment.	**M**	**E**
				competitor's pressure and market forces	**M**	**VG**
		Prevailing Cultural Norms	**FH**	Organization open to new ideas (encourage innovation)	**FH**	**VG**
				Ability to influence cultural readiness for change.	**FH**	**G**
				Knowledge-sharing culture.	**FH**	**VG**
Performance	**FH**	**Performance Expectations**	**FH**	Clarity about expected behaviour and actions	**FH**	**G**
				Appropriateness of the target outcome	**FH**	**G**
				Aggressive about setting up targets and achieving them.	**FH**	**G**
				Reliable tools to measure and a Valid measurement system	**FH**	**G**
				Justification of process owners, responsibilities, authority, and process performance targets.	**FH**	**G**
				Establish a comprehensive measurement mechanism for the process innovation performance	**FH**	**G**
				Performance measures and expected outcomes are identified, defined, and developed.	**FH**	**G**

Table continues-next page.

Capability& Capacity	**H**	**Dynamic Capability**	**H**	the appropriate level of internal competencies needed for deployment	**H**	**VG**
				the appropriate level of external competencies needed for deployment	**H**	**VG**
		Absorptive Capacity	**H**	Deployment team's ability to identify and use valuable external knowledge towards achieving successful implementation.	**H**	**VG**
				Acquisition capacity	**H**	**G**
				Assimilation capacity	**H**	**G**
				Transformation capacity	**H**	**G**
				Application (or exploitation) capacity	**H**	**G**
Resources	**H**	**Financial Resources**	**H**	Availability, adequacy and stability of Financial Resources throughout the deployment.	**H**	**E**
				Schedule Scope Budget	**H**	**VG**
		Human Resources	**FH**	Training (Education Requirements and Policies), coaching and learning opportunities, Training & education at all levels in the organisation, including technical skills development	**FH**	**VG**
				The organization encourages process ownership.	**FH**	**G**
				Employees feel free to report information on errors and defects.	**FH**	**VG**
				Employees are motivated to self-enhance and adopt a learning culture, and Educate on process capability indicators	**FH**	**G**
				Commitment to deployment and Assign Responsibilities	**FH**	**VG**
				The organization promotes the involvement of all its employees in quality and CI.	**FH**	**G**
				Motivation, HR system and Human Capability	**FH**	**G**
				Experience, selecting the right people	**FH**	**G**
				Attitudes - Habits	**FH**	**G**
				Skill, Employees' knowledge and skills	**FH**	**VG**
		Technical Resources	**VH**	Availability of enabling technologies and Infrastructure	**VH**	**E**
				IT Partnership, Subcontractor engagement	**VH**	**E**
				Data Source, Data Management and Data and Information Quality.	**VH**	**E**
				Analytics Capability and Basic consideration of IT usage.	**VH**	**E**
Collaboration	**H**	**Deployment plan**	**VH**	Availability of development plan	**VH**	**VG**
				Controls within project constraints relating to time.	**VH**	**VG**
				Controls within project constraints relating to cost.	**VH**	**VG**
				The overall quality of a deployment plan	**VH**	**VG**
				Controls within project constraints relating to scope.	**VH**	**VG**

Table continues-next page.

				Controls within project constraints relating to quality.	**VH**	**VG**
		Deployment Control	**H**	Appreciation level of project management.	**H**	**VG**
				Availability of project champion.	**H**	**VG**
				Supervision level of the deployment.	**H**	**VG**
				Adherence to ground rules.	**H**	**VG**
				Proactive quality system.	**H**	**VG**
				Communications tools implementation	**H**	**VG**
				Assurances for the control stages	**H**	**VG**
				Project management skills and G decision making.	**H**	**VG**
		Deployment Coordination	**H**	Managing the day-to-day operations of the deployment	**H**	**G**
				Ensuring awareness of deadlines and tasks the deployment team is responsible	**H**	**G**
		Flexibility	**FH**	Flexibility to accommodate changes.	**FH**	**VG**
				ability to manage uncertainty	**FH**	**VG**
		Process Visibility	**M**	Ability to see end to end and understand all aspects of the deployment at any point in time.	**M**	**G**
				Having appropriate platform, linkages, and support for information sharing	**M**	**G**

To calculate the Fuzzy IDR level of Company Z, Equations (6.1), (6.2) and (6.3) are used with the data taken from table 37. The result is shown in Table 38. Example calculations are as follows.

Primary assessment calculations for IDR11 using Equation (6.1):

$$IDR_{11} = \begin{bmatrix} (0.7, 0.8, 0.9) \otimes & (7,8,9) + \\ (0.7, 0.8, 0.9) \otimes & (5, 6.5,8) + \\ (0.7, 0.8, 0.9) \otimes & (7,8,9) + \\ (0.7, 0.8, 0.9) \otimes & (7,8,9) + \\ (0.7, 0.8, 0.9) \otimes & (7,8,9) + \\ (0.7, 0.8, 0.9) \otimes & (7,8,9) + \end{bmatrix} / \begin{bmatrix} (0.7, 0.8, 0.9) + \\ (0.7, 0.8, 0.9) + \\ (0.7, 0.8, 0.9) + \\ (0.7, 0.8, 0.9) + \\ (0.7, 0.8, 0.9) + \\ (0.7, 0.8, 0.9) \end{bmatrix} = (6.67,7.75,8.83) \tag{6.5}$$

Secondary assessment calculations for IDR_1 using Equation (6.2):

$$IDR_1 = \begin{bmatrix} (0.7, 0.8, 0.9) \otimes & (6.67,7.75, 7.83) + \\ (0.85, 0.95, 1) \otimes & (6, 7.25,8.50) + \\ (0.7, 0.8, 0.9) \otimes & (5.36,6.77,8.18) + \\ (0.3, 0.5, 0.7) \otimes & (6.92, 8,9) + \\ (0.5, 0.65, 0.8) \otimes & (6.33, 7.5,8.67) \end{bmatrix} / \begin{bmatrix} (0.7, 0.8, 0.9) \\ (0.85, 0.95, 1) \\ (0.7, 0.8, 0.9) \\ (0.3, 0.5, 0.7) \\ (0.5, 0.65, 0.8) \end{bmatrix} = (6.15,7.40,8.62) \tag{6.6}$$

The tertiary assessment calculation for the FIDRi of the case study using Equation (6.3):

$$\text{FIDRi} = \begin{bmatrix} (0.70, 0.80, 0.90) \otimes & (6.15,7.40,8.62) + \\ (0.50, 0.65, 0.80) \otimes & (5.00,6.50,8.00) + \\ (0.70, 0.80, 0.90) \otimes & (6.20,7.40,8.60) + \\ (0.70, 0.80, 0.90) \otimes & (7.59,8.60,9.36) + \\ (0.70, 0.80, 0.90) \otimes & (6.34,7.47,8.63) \end{bmatrix} / \begin{bmatrix} (0.70, 0.80, 0.90) + \\ (0.50, 0.65, 0.80) + \\ (0.70, 0.80, 0.90) + \\ (0.70, 0.80, 0.90) + \\ (0.70, 0.80, 0.90) \end{bmatrix} = (6.33, 7.51, 8.66) \tag{6.7}$$

Table 38: Linguistic approximated by fuzzy numbers

IDRi	Wi	IDRij	Wij	Wijk	IDRijk
IDR1 6.15 7.40 8.62	W_1= (0.70, 0.80, 0.90)	IDR11 6.67 7.75 8.83	W_{11}= (0.70, 0.80, 0.90)	W_{111} = (0.70, 0.80, 0.90)	R_{111} = (7, 8, 9)
				W_{112} = (0.70, 0.80, 0.90)	R_{112} = (5, 6.5, 8)
				W_{113} = (0.70, 0.80, 0.90)	R_{113} = (7, 8, 9)
				W_{114} = (0.70, 0.80, 0.90)	R_{114} = (7, 8, 9)
				W_{115} = (0.70, 0.80, 0.90)	R_{115} = (7, 8, 9)
				W_{116} = (0.70, 0.80, 0.90)	R_{116} = (7, 8, 9)
		IDR12 6.00 7.25 8.50	W_{12}= (0.85, 0.95, 1)	W_{121} = (0.85, 0.95, 1)	R_{121} = (5, 6.5, 8)
				W_{122} = (0.85, 0.95, 1)	R_{122} = (7, 8, 9)
				W_{123} = (0.85, 0.95, 1)	R_{123} = (5, 6.5, 8)
				W_{124} = (0.85, 0.95, 1)	R_{124} = (7, 8, 9)
		IDR13 5.36 6.77 8.18	W_{13}= (0.70, 0.80, 0.90)	W_{131} = (0.70, 0.80, 0.90)	R_{131} = (5, 6.5, 8)
				W_{132} = (0.70, 0.80, 0.90)	R_{132} = (5, 6.5, 8)
				W_{133} = (0.70, 0.80, 0.90)	R_{133} = (5, 6.5, 8)
				W_{134} = (0.70, 0.80, 0.90)	R_{134} = (5, 6.5, 8)
				W_{135} = (0.70, 0.80, 0.90)	R_{135} = (5, 6.5, 8)
				W_{136} = (0.70, 0.80, 0.90)	R_{136} = (5, 6.5, 8)
				W_{137} = (0.70, 0.80, 0.90)	R_{137} = (7, 8, 9)
				W_{138} = (0.70, 0.80, 0.90)	R_{138} = (5, 6.5, 8)
				W_{139} = (0.70, 0.80, 0.90)	R_{139} = (7, 8, 9)
				W_{1310} = (0.70, 0.80, 0.90)	R_{1310} = (5, 6.5, 8)
				W_{1311} = (0.70, 0.80, 0.90)	R_{1311} = (5, 6.5, 8)
			W_{14}= (0.30, 0.50, 0.70)	W_{141} = (0.30, 0.50, 0.70)	R_{141} = (5, 6.5, 8)

Table continues-next page.

				W_{142} = (0.30, 0.50, 0.70)	R_{142} = (7, 8, 9)
				W_{143} = (0.30, 0.50, 0.70)	R_{143} = (7, 8, 9)
		IDR14 6.92 8.00 9.00		W_{144} = (0.30, 0.50, 0.70)	R_{144} = (7, 8, 9)
				W_{145} = (0.30, 0.50, 0.70)	R_{145} = (8.5, 9.5, 10)
				W_{146} = (0.30, 0.50, 0.70)	R_{146} = (7, 8, 9)
		IDR15 6.33 7.50 8.67	W_{15}= (0.50, 0.65, 0.80)	W_{151} = (0.50, 0.65, 0.80)	R_{151} = (7, 8, 9)
				W_{152} = (0.50, 0.65, 0.80)	R_{152} = (5, 6.5, 8)
				W_{153} = (0.50, 0.65, 0.80)	R_{153} = (7, 8, 9)
IDR2 5.00 6.50 8.00	W_2= (0.50, 0.65, 0.80)	IDR21 5.00 6.50 8.00	W_{21}= (0.50, 0.65, 0.80)	W_{211} = (0.50, 0.65, 0.80)	R_{211} = (5, 6.5, 8)
				W_{212} = (0.50, 0.65, 0.80)	R_{212} = (5, 6.5, 8)
				W_{213} = (0.50, 0.65, 0.80)	R_{213} = (5, 6.5, 8)
				W_{214} = (0.50, 0.65, 0.80)	R_{214} = (5, 6.5, 8)
				W_{215} = (0.50, 0.65, 0.80)	R_{215} = (5, 6.5, 8)
				W_{216} = (0.50, 0.65, 0.80)	R_{216} = (5, 6.5, 8)
				W_{217} = (0.50, 0.65, 0.80)	R_{217} = (5, 6.5, 8)
IDR3 6.20 7.40 8.60	W_3= (0.70, 0.80, 0.90)	IDR31 7.00 8.00 9.00	W_{31}= (0.70, 0.80, 0.90)	W_{311} = (0.70, 0.80, 0.90)	R_{311} = (7, 8, 9)
				W_{312} = (0.70, 0.80, 0.90)	R_{312} = (7, 8, 9)
		IDR32 5.40 6.80 8.20	W_{32}= (0.70, 0.80, 0.90)	W_{321} = (0.70, 0.80, 0.90)	R_{321} = (7, 8, 9)
				W_{322} = (0.70, 0.80, 0.90)	R_{322} = (5, 6.5, 8)
				W_{323} = (0.70, 0.80, 0.90)	R_{323} = (5, 6.5, 8)
				W_{324} = (0.70, 0.80, 0.90)	R_{324} = (5, 6.5, 8)
				W_{325} = (0.70, 0.80, 0.90)	R_{325} = (5, 6.5, 8)
IDR4 7.59 8.60 9.36	W_4= (0.70, 0.80, 0.90)	IDR41 7.75 8.75 9.50	W_{41}= (0.70, 0.80, 0.90)	W_{411} = (0.70, 0.80, 0.90)	R_{411} = (8.5, 9.5, 10)
				W_{412} = (0.70, 0.80, 0.90)	R_{412} = (7, 8, 9)
		IDR42 5.80 7.10 8.40	W_{42}= (0.50, 0.65, 0.80)	W_{421} = (0.50, 0.65, 0.80)	R_{421} = (7, 8, 9)
				W_{422} = (0.50, 0.65, 0.80)	R_{422} = (5, 6.5, 8)

Table continues-next page.

				W_{423} = (0.50, 0.65, 0.80)	R_{423} = (7, 8, 9)
				W_{424} = (0.50, 0.65, 0.80)	R_{424} = (5, 6.5, 8)
				W_{425} = (0.50, 0.65, 0.80)	R_{425} = (7, 8, 9)
				W_{426} = (0.50, 0.65, 0.80)	R_{426} = (5, 6.5, 8)
				W_{427} = (0.50, 0.65, 0.80)	R_{427} = (5, 6.5, 8)
				W_{428} = (0.50, 0.65, 0.80)	R_{428} = (5, 6.5, 8)
				W_{429} = (0.50, 0.65, 0.80)	R_{429} = (5, 6.5, 8)
				W_{4210} = (0.50, 0.65, 0.80)	R_{4210} = (7, 8, 9)
		IDR43 8.50 9.50 10.00	W_{43}= (0.85, 0.95, 1)	W_{431} = (0.85, 0.95, 1)	R_{431} = (8.5, 9.5, 10)
				W_{432} = (0.85, 0.95, 1)	R_{432} = (8.5, 9.5, 10)
				W_{433} = (0.85, 0.95, 1)	R_{433} = (8.5, 9.5, 10)
				W_{434} = (0.85, 0.95, 1)	R_{434} = (8.5, 9.5, 10)
IDR5 6.34 7.47 8.63	W_5= (0.70, 0.80, 0.90)	IDR51 7.00 8.00 9.00	W_{51}= (0.85, 0.95, 1)	W_{511} = (0.85, 0.95, 1)	R_{511} = (7, 8, 9)
				W_{512} = (0.85, 0.95, 1)	R_{512} = (7, 8, 9)
				W_{513} = (0.85, 0.95, 1)	R_{513} = (7, 8, 9)
				W_{514} = (0.85, 0.95, 1)	R_{514} = (7, 8, 9)
				W_{515} = (0.85, 0.95, 1)	R_{515} = (7, 8, 9)
				W_{516} = (0.85, 0.95, 1)	R_{516} = (7, 8, 9)
		IDR52 7.00 8.00 9.00	W_{52}= (0.70, 0.80, 0.90)	W_{521} = (0.70, 0.80, 0.90)	R_{521} = (7, 8, 9)
				W_{522} = (0.70, 0.80, 0.90)	R_{522} = (7, 8, 9)
				W_{523} = (0.70, 0.80, 0.90)	R_{523} = (7, 8, 9)
				W_{524} = (0.70, 0.80, 0.90)	R_{524} = (7, 8, 9)
				W_{525} = (0.70, 0.80, 0.90)	R_{525} = (7, 8, 9)
				W_{526} = (0.70, 0.80, 0.90)	R_{526} = (7, 8, 9)
				W_{527} = (0.70, 0.80, 0.90)	R_{527} = (7, 8, 9)
				W_{528} = (0.70, 0.80, 0.90)	R_{528} = (7, 8, 9)
		IDR53 5.00 6.50 8.00	W_{53}= (0.70, 0.80, 0.90)	W_{531} = (0.70, 0.80, 0.90)	R_{531} = (5, 6.5, 8)
				W_{532} = (0.70, 0.80, 0.90)	R_{532} = (5, 6.5, 8)
			W_{54}= (0.50, 0.65, 0.80)	W_{541} = (0.50, 0.65, 0.80)	R_{541} = (7, 8, 9)

Table continues-next page.

		IDR54	7.00 8.00 9.00		W_{542} = (0.50, 0.65, 0.80)	R_{542} = (7, 8, 9)
		IDR55	5.00 6.50 8.00	W_{55}= (0.30, 0.50, 0.70)	W_{551} = (0.30, 0.50, 0.70)	R_{551} = (5, 6.5, 8)
					W_{552} = (0.30, 0.50, 0.70)	R_{552} = (5, 6.5, 8)

Equation (6.4) is used to calculate the Euclidean distances between the PIDR levels shown in Table 38 and the FIDR calculated in Equation (6.7), which are shown in Table 39. It is found, as illustrated in Figure 28 below, that the lowest distance is 0.8956, which indicates that Company Z is Very strongly Ready to deploy the reconfiguration initiative.

Table 39: Euclidean distance between FIDRi and IDRLi

D(FIDRi, IDRLi)		
Euclidean Distances (IDRi)	**Distance**	
D(FIDRi, CR)	3.2337	
D(FIDRi, VSR)	0.8956	**Very Strongly Ready**
D(FIDRi, VR)	1.7972	
D(FIDRi, R)	4.4897	
D(FIDRi, SR)	6.9448	
D(FIDRi, NR)	9.5291	
D(FIDRi, NRaA)	11.8521	

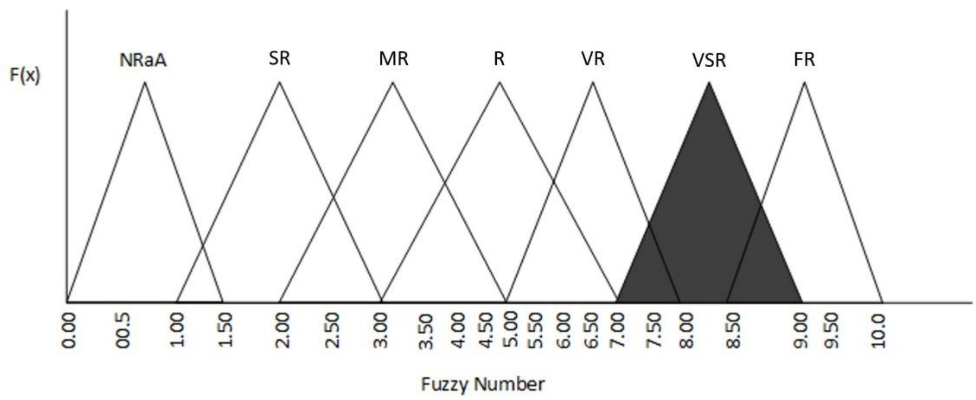


Figure 33: Linguistic levels to match FRI.

6.4.2 Improvement Proposals

Whilst Company Z is adjudged based on the assessment method presented in this thesis; the company can nonetheless seek to improve towards a fully ready state. Calculation of a set of ranking scores for the attributes in Table 40 has been used to propose areas of improvement. The fuzzy IDR index FIDR for each of the attributes is converted to crisp values, and the ranking scores are derived from the values obtained. The FIDR is computed as the product of the attribute performance ratings R_{ijk} and the inverse of the associated importance weights W'_{ijk} as shown in Equation (6.8).

$$\text{FIDR}_{ijk} = W'_{ijk} \otimes R_{ijk} \quad (6.8)$$

where:
W'_{ijk} = Complement of the importance weight of k^{th} attribute in j^{th} factor in i^{th} dimension.
$FIDR_{ijk}$ = Performance rating of the k^{th} attribute in j^{th} factor in i^{th} dimension.

Table 39 shows the FIDR for each attribute. Using the centroid method for membership function (a, b, c), the crisp values (ranking scores) of the FIDRis, are calculated. Lower(a), middle(b) and upper (c) values of triangular fuzzy numbers of the FIDR. Following is an example calculation of the FIDR for the first attribute in the first factor in the first dimension (FIDR_{111})).

$$\text{FIDR}_{111} = (0.70, 0.80, 0.90) \otimes (7, 8, 9) = 0.7, 1.6, 2.7$$

Equation (6.9) is used to convert FPIs, which are fuzzy ranking scores, to crisp values.

$$\text{Ranking score} = \frac{a+4b+c}{6} \quad (6.9)$$

Table 40 shows the results of the crisp ranking scores. As an example, the ranking score for IDR111, which is the first attribute pertaining to the first factor in the first dimension, is calculated as follows.

$$(\text{Ranking score})_{111} = \frac{0.7+(4 \times 1.6)+2.7}{6} = 1.63$$

Table 40: Attributes ranking score for the case study.

IDR_{ijk}	**R_{ijk}**	**W^1_{ijk}**	**FPII**	**Ranking score**
IDR111	R_{111} = (7, 8, 9)	W_{111} = (0.70, 0.80, 0.90)	0.7, 1.6, 2.7	1.63
IDR112	R_{112} = (5, 6.5, 8)	W_{112} = (0.70, 0.80, 0.90)	0.5, 1.3, 2.4	1.35
IDR113	R_{113} = (7, 8, 9)	W_{113} = (0.70, 0.80, 0.90)	0.7, 1.6, 2.7	1.63
IDR114	R_{114} = (7, 8, 9)	W_{114} = (0.70, 0.80, 0.90)	0.7, 1.6, 2.7	1.63
IDR115	R_{115} = (7, 8, 9)	W_{115} = (0.70, 0.80, 0.90)	0.7, 1.6, 2.7	1.63
IDR116	R_{116} = (7, 8, 9)	W_{116} = (0.70, 0.80, 0.90)	0.7, 1.6, 2.7	1.63
IDR121	R_{121} = (5, 6.5, 8)	W_{121} = (0.85, 0.95, 1)	0, 0.325, 1.2	0.42
IDR122	R_{122} = (7, 8, 9)	W_{122} = (0.85, 0.95, 1)	0, 0.4, 1.35	0.49
IDR123	R_{123} = (5, 6.5, 8)	W_{123} = (0.85, 0.95, 1)	0, 0.325, 1.2	0.42

Table continues-next page.

IDR124	R_{124} = (7, 8, 9)	W_{124} = (0.85, 0.95, 1)	0, 0.4, 1.35	0.49
IDR131	R_{131} = (5, 6.5, 8)	W_{131} = (0.70, 0.80, 0.90)	0.5, 1.3, 2.4	1.35
IDR132	R_{132} = (5, 6.5, 8)	W_{132} = (0.70, 0.80, 0.90)	0.5, 1.3, 2.4	1.35
IDR133	R_{133} = (5, 6.5, 8)	W_{133} = (0.70, 0.80, 0.90)	0.5, 1.3, 2.4	1.35
IDR134	R_{134} = (5, 6.5, 8)	W_{134} = (0.70, 0.80, 0.90)	0.5, 1.3, 2.4	1.35
IDR135	R_{135} = (5, 6.5, 8)	W_{135} = (0.70, 0.80, 0.90)	0.5, 1.3, 2.4	1.35
IDR136	R_{136} = (5, 6.5, 8)	W_{136} = (0.70, 0.80, 0.90)	0.5, 1.3, 2.4	1.35
IDR137	R_{137} = (7, 8, 9)	W_{137} = (0.70, 0.80, 0.90)	0.7, 1.6, 2.7	1.63
IDR138	R_{138} = (5, 6.5, 8)	W_{138} = (0.70, 0.80, 0.90)	0.5, 1.3, 2.4	1.35
IDR139	R_{139} = (7, 8, 9)	W_{139} = (0.70, 0.80, 0.90)	0.7, 1.6, 2.7	1.63
IDR1310	R_{1310} = (5, 6.5, 8)	W_{1310} = (0.70, 0.80, 0.90)	0.5, 1.3, 2.4	1.35
IDR1311	R_{1311} = (5, 6.5, 8)	W_{1311} = (0.70, 0.80, 0.90)	0.5,1.3, 2.4	1.35
IDR141	R_{141} = (5, 6.5, 8)	W_{141} = (0.30, 0.50, 0.70)	1.5, 3.25, 5.6	3.35
IDR142	R_{142} = (7, 8, 9)	W_{142} = (0.30, 0.50, 0.70)	2.1, 4, 6.3	4.07
IDR143	R_{143} = (7, 8, 9)	W_{143} = (0.30, 0.50, 0.70)	2.1, 4, 6.3	4.07
IDR144	R_{144} = (7, 8, 9)	W_{144} = (0.30, 0.50, 0.70)	2.1, 4, 6.3	4.07
IDR145	R_{145} = (8.5, 9.5, 10)	W_{145} = (0.30, 0.50, 0.70)	2.55, 4.75, 7	4.76
IDR146	R_{146} = (7, 8, 9)	W_{146} = (0.30, 0.50, 0.70)	2.1, 4, 6.3	4.07
IDR151	R_{151} = (7, 8, 9)	W_{151} = (0.50, 0.65, 0.80)	1.4, 2.8, 4.5	2.85
IDR152	R_{152} = (5, 6.5, 8)	W_{152} = (0.50, 0.65, 0.80)	1, 2.275, 4	2.35
IDR153	R_{153} = (7, 8, 9)	W_{153} = (0.50, 0.65, 0.80)	1.4, 2.8, 4.5	2.85
IDR211	R_{211} = (5, 6.5, 8)	W_{211} = (0.50, 0.65, 0.80)	1, 2.275, 4	2.35
IDR212	R_{212} = (5, 6.5, 8)	W_{212} = (0.50, 0.65, 0.80)	1, 2.275, 4	2.35
IDR213	R_{213} = (5, 6.5, 8)	W_{213} = (0.50, 0.65, 0.80)	1, 2.275, 4	2.35
IDR214	R_{214} = (5, 6.5, 8)	W_{214} = (0.50, 0.65, 0.80)	1, 2.275, 4	2.35
IDR215	R_{215} = (5, 6.5, 8)	W_{215} = (0.50, 0.65, 0.80)	1, 2.275, 4	2.35
IDR216	R_{216} = (5, 6.5, 8)	W_{216} = (0.50, 0.65, 0.80)	1, 2.275, 4	2.35
IDR217	R_{217} = (5, 6.5, 8)	W_{217} = (0.50, 0.65, 0.80)	1, 2.275, 4	2.35
IDR311	R_{311} = (7, 8, 9)	W_{311} = (0.70, 0.80, 0.90)	0.7, 1.6, 2.7	1.63
IDR312	R_{312} = (7, 8, 9)	W_{312} = (0.70, 0.80, 0.90)	0.7, 1.6, 2.7	1.63
IDR321	R_{321} = (7, 8, 9)	W_{321} = (0.70, 0.80, 0.90)	0.7, 1.6, 2.7	1.63
IDR322	R_{322} = (5, 6.5, 8)	W_{322} = (0.70, 0.80, 0.90)	0.5, 1.3, 2.4	1.35
IDR323	R_{323} = (5, 6.5, 8)	W_{323} = (0.70, 0.80, 0.90)	0.5, 1.3, 2.4	1.35
IDR324	R_{324} = (5, 6.5, 8)	W_{324} = (0.70, 0.80, 0.90)	0.5, 1.3, 2.4	1.35
IDR325	R_{325} = (5, 6.5, 8)	W_{325} = (0.70, 0.80, 0.90)	0.5, 1.3, 2.4	1.35
IDR411	R_{411} = (8.5, 9.5, 10)	W_{411} = (0.70, 0.80, 0.90)	0.85, 1.9, 3	1.91
IDR412	R_{412} = (7, 8, 9)	W_{412} = (0.70, 0.80, 0.90)	0.7, 1.6, 2.7	1.63
IDR421	R_{421} = (7, 8, 9)	W_{421} = (0.50, 0.65, 0.80)	1.4, 2.8, 4.5	2.85
IDR422	R_{422} = (5, 6.5, 8)	W_{422} = (0.50, 0.65, 0.80)	1, 2.275, 4	2.35
IDR423	R_{423} = (7, 8, 9)	W_{423} = (0.50, 0.65, 0.80)	1.4, 2.8, 4.5	2.85
IDR424	R_{424} = (5, 6.5, 8)	W_{424} = (0.50, 0.65, 0.80)	1, 2.275, 4	2.35
IDR425	R_{425} = (7, 8, 9)	W_{425} = (0.50, 0.65, 0.80)	1.4, 2.8, 4.5	2.85
IDR426	R_{426} = (5, 6.5, 8)	W_{426} = (0.50, 0.65, 0.80)	1, 2.275, 4	2.35
IDR427	R_{427} = (5, 6.5, 8)	W_{427} = (0.50, 0.65, 0.80)	1, 2.275, 4	2.35
IDR428	R_{428} = (5, 6.5, 8)	W_{428} = (0.50, 0.65, 0.80)	1, 2.275, 4	2.35
IDR429	R_{429} = (5, 6.5, 8)	W_{429} = (0.50, 0.65, 0.80)	1, 2.275, 4	2.35

Table continues-next page.

IDR4210	R_{4210} = (7, 8, 9)	W_{4210} = (0.50, 0.65, 0.80)	1.4, 2.8, 4.5	2.85
IDR431	R_{431} = (8.5, 9.5, 10)	W_{431} = (0.85, 0.95, 1)	0, 0.475, 1.5	0.57
IDR432	R_{432} = (8.5, 9.5, 10)	W_{432} = (0.85, 0.95, 1)	0, 0.475, 1.5	0.57
IDR433	R_{433} = (8.5, 9.5, 10)	W_{433} = (0.85, 0.95, 1)	0, 0.475, 1.5	0.57
IDR434	R_{434} = (8.5, 9.5, 10)	W_{434} = (0.85, 0.95, 1)	0, 0.475, 1.5	0.57
IDR511	R_{511} = (7, 8, 9)	W_{511} = (0.85, 0.95, 1)	0, 0.4, 1.35	0.49
IDR512	R_{512} = (7, 8, 9)	W_{512} = (0.85, 0.95, 1)	0, 0.4, 1.35	0.49
IDR513	R_{513} = (7, 8, 9)	W_{513} = (0.85, 0.95, 1)	0, 0.4, 1.35	0.49
IDR514	R_{514} = (7, 8, 9)	W_{514} = (0.85, 0.95, 1)	0, 0.4, 1.35	0.49
IDR515	R_{515} = (7, 8, 9)	W_{515} = (0.85, 0.95, 1)	0, 0.4, 1.35	0.49
IDR516	R_{516} = (7, 8, 9)	W_{516} = (0.85, 0.95, 1)	0, 0.4, 1.35	0.49
IDR521	R_{521} = (7, 8, 9)	W_{521} = (0.70, 0.80, 0.90)	0.7, 1.6, 2.7	1.63
IDR522	R_{522} = (7, 8, 9)	W_{522} = (0.70, 0.80, 0.90)	0.7, 1.6, 2.7	1.63
IDR523	R_{523} = (7, 8, 9)	W_{523} = (0.70, 0.80, 0.90)	0.7, 1.6, 2.7	1.63
IDR524	R_{524} = (7, 8, 9)	W_{524} = (0.70, 0.80, 0.90)	0.7, 1.6, 2.7	1.63
IDR525	R_{525} = (7, 8, 9)	W_{525} = (0.70, 0.80, 0.90)	0.7, 1.6, 2.7	1.63
IDR526	R_{526} = (7, 8, 9)	W_{526} = (0.70, 0.80, 0.90)	0.7, 1.6, 2.7	1.63
IDR527	R_{527} = (7, 8, 9)	W_{527} = (0.70, 0.80, 0.90)	0.7, 1.6, 2.7	1.63
IDR528	R_{528} = (7, 8, 9)	W_{528} = (0.70, 0.80, 0.90)	0.7, 1.6, 2.7	1.63
IDR531	R_{531} = (5, 6.5, 8)	W_{531} = (0.70, 0.80, 0.90)	0.5, 1.3, 2.4	1.35
IDR532	R_{532} = (5, 6.5, 8)	W_{532} = (0.70, 0.80, 0.90)	0.5, 1.3, 2.4	1.35
IDR541	R_{541} = (7, 8, 9)	W_{541} = (0.50, 0.65, 0.80)	1.4, 2.8, 4.5	2.85
IDR542	R_{542} = (7, 8, 9)	W_{542} = (0.50, 0.65, 0.80)	1.4, 2.8, 4.5	2.85
IDR551	R_{551} = (5, 6.5, 8)	W_{551} = (0.30, 0.50, 0.70)	1.5, 3.25, 5.6	3.35
IDR552	R_{552} = (5, 6.5, 8)	W_{552} = (0.30, 0.50, 0.70)	1.5, 3.25, 5.6	3.35

Company Z adopted a threshold of 0.5 for the ranking scores, a recommendation of the company's management. Tables 41 show the prioritised attributes.

Table 41: Prioritised Attributes

Dimension	Factor	Attribute	Ranking Score
Context	Innovation Context	Maturity level of the innovation	0.42
		Protection of innovation	0.42
		Knowledge and understanding of the new processes and their workflow	0.49
		Specific and enabling infrastructure	0.49
Collaboration	Deployment plan	Availability of development plan	0.49
		Controls within project constraints relating to time.	0.49
		Controls within project constraints relating to cost.	0.49
		The overall quality of a deployment plan	0.49
		Controls within project constraints relating to scope.	0.49
		Controls within project constraints relating to quality.	0.49

6.5 Discussion of Results

This thesis has proposed in this chapter a process innovation deployment readiness assessment model which allows manufacturing companies to assess their process innovation deployment readiness level concerning their process innovation initiatives and facilitate the use of a range of process innovation deployment readiness attributes. The process innovation deployment readiness attributes identified for Company Z attributes worked well for the company, and they were able to readily allocate performance values to the attributes. Collecting data was much easier due to the proposed linguistic variables for the company, which facilitated a meaningful demonstration of performance for the company. Adding weights to the attributes, factors, and dimensions was a straightforward and fairly simple task for the case study company as the weights attached are linguistic values. Moreover, the assigned weights were based on their experience in contract manufacturing in the electronics sector, which makes the process straightforward for the company. The result of the assessment wasn't a surprise for the case study company; they envisage a high state of preparedness.

Due to the simplicity of the method presented in this research, the case study company is interested in using the model beyond the current exercise. The method is user friendly, and the company found it useful in obtaining the relevant data and plugging the data into the expressions to calculate deployment readiness level. The case study company find it attractive and easy to understand the innovation deployment readiness level and believes it would help in making better implementation decisions.

Based on the calculation and the result obtained, company Z has a very strongly ready process innovation deployment readiness state, an outcome the company readily relates to. Reflecting on the outcome, Company Z believes the very strongly ready process innovation deployment readiness state captures the very good preparation they made for implementing the process innovation. Even though they were not fully ready, the company was happy to proceed with the deployment. This corroborates the findings in Chapter 5 that manufacturing companies do not necessarily have to be fully ready prior to deploying their process innovation initiatives. In general, accepting the level of readiness with which a company operates will depend on the company's deployment readiness targets, strategy, and expectations (Javahernia & Sunmola, 2017). As discussed and reported in Chapter 5, the majority of manufacturing companies are happy to proceed with the deployment once they have 71 – 80% readiness to deploy innovation which is in line with what almost all companies are doing (Javahernia & Sunmola, 2020), and so is for Company Z in the case study.

The main strengths of company Z regarding the process innovation deployment readiness are:

- Government support, policies and regulations, Legal environment
- Suppliers and contractors and their cooperation.
- Availability of external support services in the national and international business environment of supporting industries
- Competitor's pressure and market forces
- Ability to see end to end and understand all aspects of the deployment at any point in time
- Having appropriate platform, linkages, and support for information sharing

As it is clear from this study, company Z has its highest-ranking score on Government support, policies and regulations, and Legal environment. The process innovation initiative of Company Z is supported by a funded grant. In addition, there are clear policies, regulations and legal framework that supports the initiative. The products that they will be manufactured on the implementation of the process innovation initiative require stringent standards. The remainder of the above list of strengths is, in general, typical of the target standard practices of the company, and the company is delighted that it is picked up in the assessment.

According to Table 41, there are two main dimensions to consider when aiming to improve the currently assessed level to achieve a fully ready state. These are context (specifically innovation context) and coordination (using deployment plan). For the innovation context, the maturity of the process innovation initiative the company is intending to implement is low, and it appears to need more research and development to bring the readiness level of the innovation up, to better support a fully ready state of deployment. This is in part a reason for the implementation the company is working on, supporting its research and development of smart reconfigurable manufacturing of its processes. It is worth noting that not being fully ready to deploy may entail some uncertainties about the deployment and successful outcome. This is not helped by not having a good deployment plan in place. Although Company Z has a deployment plan in place, areas of improvement picked up by the assessment centres more around a need to have extra support for controls within project constraints relating to scope, time and cost. Another area that will affect the deployment plan significantly is the overall quality of the deployment plan, which the assessment suggests needs to be reconsidered for company Z.

6.6 Chapter summary

This chapter presents a manufacturing process innovation deployment readiness assessment model. The model is based on fuzzy logic, and the approach adopted for the assessment is described in the chapter. The approach centres on the deployment readiness assessment data organisation structure presented in Chapter 4 of this thesis involving dimensions, factors, and attributes of manufacturing process innovation deployment readiness. The use of linguistic variables as part of the fuzzy method adopted in this research makes the data collection much easier. The innovation deployment readiness assessment model has been used in a case study company (Company Z). The company's management was found to be very strongly ready to deploy its process innovation initiative. Seven levels of process innovation deployment levels were suggested, namely fully ready, very strongly ready, very ready, ready, moderately ready, slightly ready, and not ready at all. Although Company Z is happy to proceed with the development given that they were found to be very strongly ready, the assessment model highlighted two areas of improvement for Company Z, namely relating to innovation context and availability and use of deployment plans, particularly for coordinating the deployment. The case study illustrated the assessment approach put forward, and its acceptance by the case study company is an indication of its value to manufacturing companies.

7 Conclusions and areas of future work

7.1 Conclusions

Innovation is increasingly a priority for manufacturing companies, necessitated by the intense competition they face, especially when operating in global markets. The saying goes that innovation is a precondition for survival. This thesis investigates the implementation of process innovation with a focus on the pre-implementation stage. Implementation of process innovation initiatives in manufacturing is acknowledged to be an important and challenging phase of process innovation, more so in the pre-implementation phase in which it is necessary for manufacturing organisations to attain an appropriate level of readiness prior to deploying their process innovation initiatives.

Process innovation is important to enterprises as it could help in leveraging advances in technologies, enhancing productivity, and gaining a competitive advantage. It is the development of an organization's production or service operations, input materials, task specifications, work and information flow mechanisms, and equipment through the introduction of new elements, including new technologies and new practices. To benefit from a process innovation initiative, it is necessary that the deployment of the initiative is successful. Manufacturing companies that fail to deliver process innovation successfully are typically those that do not meet the appropriate level of deployment readiness.

A continuous improvement philosophy for the deployment of manufacturing process innovation is adopted in this thesis, with a methodology that comprises five main steps namely (see Chapter 2 Section 2.9): 1) Set out the objectives of the deployment, 2) Develop a deployment plan, 3) Assess readiness to deploy, 4) Identify areas of improvement given the current level of deployment readiness, and 5) if necessary, make improvements and return to Step 3, otherwise processed to implement. Fundamental to this philosophy is knowledge and understanding of the factors that influence deployment readiness and the influences key constructs have on attaining satisfactory deployment readiness states. The research reported in this thesis seeks to provide this required knowledge and understanding. In addition, it also zooms in on Steps 3 and 4 of the methodology highlighted above. A mixed set of research methods were used, including a traditional literature review, questionnaire survey, structural equation modelling, fuzzy logic, and case study. The conclusion of the thesis is as follows.

1. Manufacturing companies can effectively attain appropriate process innovation deployment readiness levels using a scientific approach such as that set out in this thesis, i.e., based on the five-step deployment readiness methodology within a continuous improvement framework.
2. Process innovation deployment readiness levels consist of several states, two of which are prepared and fully ready. The thesis makes a distinction between preparedness and being fully ready to deploy process innovation initiatives in manufacturing. Process innovation deployments levels put forward in this thesis are: not at all ready, slightly ready, moderately ready, ready, very Ready, very strongly Ready, and Fully Ready. A manufacturing company may be considered prepared to deploy their process innovation initiative when their deployment readiness level is assessed to be at the either ready, very ready, or very strongly ready levels.
3. Preparedness is a necessary but not sufficient condition for attaining a full readiness state in the context of manufacturing process innovation. Other conditions identified in this thesis include having a deployment plan and an appropriate climate for innovation.
4. Manufacturing companies do not necessarily have to attain a full readiness state before implementing their process innovation. This conclusion is based on the perception of manufacturing managers obtained in this thesis that, on average, 71 – 80% level of deployment readiness (i.e., a very ready state) would be enough to start implementation. The managers indicated that their manufacturing companies would not typically wait to be 100% ready before they deploy. None appears to deploy if they are 40% or less ready.
5. Manufacturing flexibility can influence preparedness to deploy process innovation initiatives in manufacturing. Specifically, this thesis found that labour flexibility has a significant positive influence on preparedness. However, no such support is found for mix flexibility. It is important for manufacturing companies to leverage the right flexibility when preparing to deploy their process innovation initiatives.
6. Several factors are found to influence manufacturing process innovation deployment readiness, namely, absorptive capacity, deployment control,

deployment coordination, deployment plan, dynamic capability, external factors, resources (financial and human), flexibility, context (innovation context, organisational and leadership context), and performance expectations. The factors can be characterised along the context dimensions for process innovation, performance, capability and capacity, resources, and collaboration. The dimensions, factors, and associated attributes of process innovation deployment readiness form a good basis for assessing deployment readiness levels.

7. The fuzzy logic method provides an attractive approach to assessing deployment readiness and makes the assessment accessible in manufacturing when based on the dimensions-factors-attributes framework put forward in this thesis. A case study reported in this thesis demonstrates the usefulness of the approach, including its ability to recommend areas in which deployment readiness can be improved.

Overall, putting together the insights and methods provided in this thesis, manufacturing companies can begin to customise the process innovation deployment methodology put forward in this thesis to suit their specific context and vision.

7.2 Areas of future work

There are some recognised limitations of this thesis.

First, the approach to process innovation deployment followed in this thesis assumes homogeneity of the manufacturing industry. While this assumption is good for research purposes, however, there may be value in customising the methods and findings to account for possible differences between sectors of the manufacturing industry, e.g., electronics, oil and gas, food, etc. Future work can extend the findings to other sectors, manufacturing processes and environments.

Second, the conceptual framework studies in this thesis account for some of the key constructs that can influence process innovation deployment readiness. There is scope for future work in these areas to bring into the framework other potential constructs, particularly when focusing on individual manufacturing sector differences.

Third, the evaluation of the conceptual framework is based on data from a sample of UK manufacturing companies represented by their manufacturing managers. An area of future work could be a comparative study of a conceptual framework for manufacturing process innovation deployment across countries and cultures.

Fourth, the link between preparedness and full readiness developed in this thesis is interesting, and there is scope for future work in this area. For example, a decision framework may be developed to facilitate transitions between deployment readiness levels, including how to make the leap between a prepared state to a full readiness state of process innovation deployment.

Fifth, the relationship between manufacturing flexibility and manufacturing process innovation deployment appears to be a rich area of future research, e.g., Javahernia et al. (2017). Future work can research the optimal portfolio of manufacturing flexibilities companies should pay attention to when deploying process innovation initiatives.

Sixth, a cut-off value is required for a recommendation of improvement areas arising from the assessment of process innovation deployment readiness level. The cut-off value used in the case study reported in this thesis was suggested by the case study company based on experience. Future work can investigate an intelligent decision-theoretic approach for specifying the cut-off point.

Seventh, the fuzzy method presented in this research present quite a good approach for assessing deployment readiness level, and this can be further improved through future work. For example, the fuzzy approach can be integrated with methods such as simulation (Alireza and Sunmola, 2017) and those offered by industry 4.0, such as machine learning, AI and data analytics.

8 Appendices

8.1 Survey Questionnaire


2017-18

Survey Questionnaire

Framework for Implementing Manufacturing Process Innovation

SCHOOL OF ENGINEERING AND TECHNOLOGY
UNIVERSITY OF HERTFORDSHIRE
PROTOCOL NUMBER: ENT/PGR/UH/02833

University of Hertfordshire School of Engineering and Technology

Survey Questionnaire
Framework for Assessing Readiness to Implement Process Innovation
School of Engineering and Technology
University of Hertfordshire

Dear Participant:

My name is Alireza Javahernia, a PhD student in the School of Engineering and Technology, University of Hertfordshire. I am researching methodology for deploying process innovation in manufacturing for my PhD.

I am inviting you to kindly participate in this research study by completing the attached questionnaire.

There is no compensation for responding nor is there any known risk.

If you choose to participate in this project, please answer all questions and return the completed questionnaires. Participation is strictly voluntary, and you may refuse to participate at any time.

Your answers will be treated as completely confidential and will only be released as part of a statistical analysis.

Thank you for taking the time to assist in the research. It is hoped that the results will be of practical value to the industry.

Kind regards,

Alireza Javahernia
PhD Research Student
School of Engineering and Technology,
University of Hertfordshire,
College Lane Campus,
Hatfield AL10 9AB UK

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PARTICIPANT INFORMATION SHEET

1 **Title of study**
Framework for Implementing Manufacturing Process Innovation.

2 **Introduction**
You are being invited to take part in a study. Before you decide whether to do so, it is important that you understand the research that is being done and what your involvement will include. Please take the time to read the following information carefully and discuss it with others if you wish. Do not hesitate to ask us anything that is not clear or for any further information you would like to help you make your decision. Please do take your time to decide whether or not you wish to take part. The University's regulations governing the conduct of studies involving human participants can be accessed via this link: http://sitem.herts.ac.uk/secreg/upr/RE01.htm Thank you for reading this.

3 **What is the purpose of this study?**
I am developing a methodology for implementing manufacturing process innovation with a focus on pre-implementation phase. The pre-implementation phase is an essential phase for enabling successful implementation of manufacturing process innovation. Emphasis will be on deployment-related issues.

4 **Do I have to take part?**
It is completely up to you whether or not you decide to take part in this study. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. Agreeing to join the study does not mean that you have to complete it. You are free to withdraw at any stage without giving a reason. A decision to withdraw at any time, or a decision not to take part at all, will not affect any treatment/care that you may receive (should this be relevant).

5 **Are there any age or other restrictions that may prevent me from participating?** No.

6 **How long will my part in the study take?** Approximately 40 minutes to complete.

7 **What will happen to me if I take part?** Nothing.

8 **What are the possible disadvantages, risks or side effects of taking part?**
There is no disadvantages, risks or side effect.

9 **What are the possible benefits of taking part?** The results will be of practical value to the industry.

10 **How will my taking part in this study be kept confidential?**
Your answers will be treated as completely confidential and will only be released as part of a statistical analysis.

11 **Audio-visual material?** Audio-visual materials will not be used.

12 **What will happen to the data collected within this study?** The data will be anonymised prior to storage.

13 **Will the data be required for use in further studies?** The data will not be used in any further studies.

14 **Who has reviewed this study?** The University of Hertfordshire Science and Technology Ethics Committee with Delegated Authority.

15 **Factors that might put others at risk?** Please note that if, during the study, any medical conditions or non-medical circumstances such as unlawful activity become apparent that might or had put others at risk, the University may refer the matter to the appropriate authorities.

16 **Who can I contact if I have any questions?** If you would like further information or would like to discuss any details personally, please get in touch with me, in writing, by phone or by email: *a.javahernia@herts.ac.uk*

Although we hope it is not the case, if you have any complaints or concerns about any aspect of the way you have been approached or treated during the course of this study, please write to the University's Secretary and Registrar.

Thank you very much for reading this information and giving consideration to taking part in this study.

General information: Please provide the following general information about your firm.

Title or position of the respondent: ________________________________

Experience implementing process innovation: (Please tick only one)

☐ Less than a year ☐ 1 to 3 year's
☐ 4 to 5 year's ☐ More than 5 years

Organisation's business type and primary line of business: (Please tick only one)

☐ Financial service ☐ Automotive industry ☐Construction
☐ IT-Technology ☐ Electrical industry ☐ Manufacturing
☐ Service industry ☐ Telecommunication ☐ Mechanical industry
☐ Pharmaceutical industry ☐ Designee consultancy
☐ Other (please specify): ______________________

Size of your organisation (number of employees): (Please tick only one)

☐ Less than 20 ☐ 20-50 ☐ 51-100 ☐ 101-200
☐ 201-500 ☐ 501-1000 ☐ More than 1000

Please answer all the questions.

To what extent do you agree/disagree with the following statements?

A. Mix flexibility

1) We can produce a wide variety of products in our plants.
Strongly disagree 1 ☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐Strongly agree

2) We can produce different product types without major changeover.
Strongly disagree 1 ☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐Strongly agree

3) We can build different products in the same plants at the same time.
Strongly disagree 1 ☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐Strongly agree

4) We can produce, simultaneously or periodically, multiple products in a steady-state operating mode.
Strongly disagree 1 ☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐Strongly agree

5) We can vary product combinations from one period to the next.
Strongly disagree 1 ☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐Strongly agree

6) We can changeover quickly from one product to another.
Strongly disagree 1 ☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐Strongly agree

Please answer all the questions.

To what extent do you agree/disagree with the following statements?

B. Labour flexibility

7) Workers can perform many types of operations effectively.
Strongly disagree 1 ☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐Strongly agree

8) A typical worker can use many different tools effectively.
Strongly disagree 1 ☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐Strongly agree

9) Cross-trained workers can perform a broad range of manufacturing tasks effectively in the organisation.
Strongly disagree 1 ☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐Strongly agree

10) Workers can operate various types of machines.
Strongly disagree 1 ☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐Strongly agree

11) Workers can be transferred easily between organisational units.
Strongly disagree 1 ☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐Strongly agree

Please answer all the questions.

To what extent do you agree/disagree with the following statements?

C. Deployment plan

A deployment plan is a detailed proposal for implementing innovation initiative in a target environment. A deployment plan can be either a) explicitly set out and formalised, or b) informally set-out i.e. implicit.

12) Deployment Plan has timelines for actions. Plan provides a schedule of activities to be accomplished.
Strongly disagree 1 ☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐Strongly agree

13) Deployment Plan provides a description of the tasks/activities involved in a manufacturing process deployment.
Strongly disagree 1 ☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐Strongly agree

14) Deployment Plan describes the support resources required for the deployment, as well as the documentation, necessary personnel and training requirements, outstanding issues and deployment impacts to the manufacturing environment.
Strongly disagree 1 ☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐Strongly agree

15) Deployment Plan describes committed and proposed staffing requirements. Describe the training, if any, to be provided for staff.
Strongly disagree 1 ☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐Strongly agree

16) We consider our organisation to be innovative.
Strongly disagree 1 ☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐Strongly agree

Please answer all the questions.

To what extent do you agree/disagree with the following statements?

D. Climate for innovation

17) The reward system here encourages innovation.
Strongly disagree 1 ☐ *2*☐ *3*☐ *4*☐ *5*☐ *6*☐ *7*☐*Strongly agree*

18) The organisation publicly recognizes those who are innovative
Strongly disagree 1 ☐ *2*☐ *3*☐ *4*☐ *5*☐ *6*☐ *7*☐*Strongly agree*

19) Top management provides resources, guidance, means and encouragement.
Strongly disagree 1 ☐ *2*☐ *3*☐ *4*☐ *5*☐ *6*☐ *7*☐*Strongly agree*

Please answer all the questions.

To what extent do you agree/disagree with the following statements, in the context of your company?

E. Innovation Deployment Preparedness

20) There is a comprehensive deployment team in place (e.g., representatives from multiple areas of the organisation).
Strongly disagree 1 ☐ *2*☐ *3*☐ *4*☐ *5*☐ *6*☐ *7*☐*Strongly agree*

21) There is a deployment framework selected to guide the implementation innovation process.
Strongly disagree 1 ☐ *2*☐ *3*☐ *4*☐ *5*☐ *6*☐ *7*☐*Strongly agree*

22) There is a communications plan to share progress of the implementation plan with multiple stakeholders, regardless of their direct involvement.
Strongly disagree 1 ☐ *2*☐ *3*☐ *4*☐ *5*☐ *6*☐ *7*☐*Strongly agree*

23) We have access to real time information.
Strongly disagree 1 ☐ *2*☐ *3*☐ *4*☐ *5*☐ *6*☐ *7*☐*Strongly agree*

F. Innovation Deployment Full Readiness

24) We are fully ready prior to deploying the process innovation initiatives.
Strongly disagree 1 ☐ *2*☐ *3*☐ *4*☐ *5*☐ *6*☐ *7*☐*Strongly agree*

Please answer all the questions.

G. Perceptions on Process Innovation Deployment and Planning

25) What level of confidence regarding implementation success will your company normally require in order to proceed with implementing process innovation?

	<40%	41%-50%	51%-60%	61%-70%	71%-80%	81%-95%	>95%	
Low	1 ☐	2☐	3☐	4☐	5☐	6☐	7☐	High

26) In what ways do you feel planning can help improve successful implementation of process innovation?

Please answer all the questions.

27) What do you think a deployment plan should contain in the context of implementing manufacturing process innovation?

Closing and Appreciation

Thank you for taking the time to assist me in my educational endeavours.

It is hoped that the results will be of practical value to the industry.

Please answer all the questions.

8.2 Sample introductory email to the participants

Dear ….,

My name is Alireza Javahernia, a PhD candidate in the School of Engineering and Computer Science, University of Hertfordshire. I am researching Deploying Process Innovation in Manufacturing for my PhD. As part of my research, the online questionnaire will be used, and this will be via the Bristol Online Surveys (BOS). I am establishing a conceptual framework that identifies the relationship between factors that influence process innovation deployment.
The participants are a sample drawn from professional manufacturing managers employed in manufacturing companies based in the UK. The participant would normally have experience in implementing manufacturing process innovation and/or continuous improvement programmes in manufacturing.

Your contributions to this research will be of significant value to us and the industry.
Let me know if you have any questions regarding the questionnaire, please.

I have to mention that the questionnaire is fairly lengthy but well received by participants who have completed it, typically in about 30 minutes.

I would very much appreciate your help.

The online questionnaire is available via the link below, ready to complete.

LINK to Click

Regards,
Alireza Javahernia

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